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Charters Without Lotteries: Testing Takeovers in New Orleans and Boston

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ABSTRACT

Charters Without Lotteries: Testing Takeovers in New Orleans and Boston^{*}

Lottery estimates suggest oversubscribed urban charter schools boost student achievement markedly. But these estimates needn't capture treatment effects for students who haven't applied to charter schools or for students attending charters for which demand is weak. This paper reports estimates of the effects of charter school attendance on middle-schoolers in charter takeovers in New Orleans and Boston. Takeovers are traditional public schools that close and then re-open as charter schools. Students enrolled in schools designated for closure are eligible for "grandfathering" into the new schools; that is, they are guaranteed seats. We use this fact to construct instrumental variables estimates of the effects of passive charter attendance: the grandfathering instrument compares students at schools designated for takeover with students who appear similar at baseline and who were attending similar schools not yet closed, while adjusting for possible violations of the exclusion restriction in such comparisons. Estimates for a large sample of takeover schools in the New Orleans Recovery School District show substantial gains from takeover enrollment. In Boston, where we can compare grandfathering and lottery estimates for a middle school, grandfathered students see achievement gains at least as large as the gains for students assigned seats in lotteries. A non-charter Boston turnaround intervention that had much in common with the charter treatment generates gains as large as those seen for takeovers, but other more modest turnaround interventions produce much smaller effects.

JEL Classification: I21, I28, J24, C26, C36

Keywords: education production, education reform, instrumental variables, compliers

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No child's chance in life should be determined by the luck of a lottery

– President Obama (quoted in *The Boston Globe*, March 13, 2011)

1 Introduction

The question of how best to improve large urban school districts remains a touchstone in the debate over American school reform. The role of charter schools – publicly funded schools that operate outside the public sector – is especially controversial. Nationwide, charter school enrollment grew from under one percent in 2000 to over four percent in 2011. Charter expansion has since continued apace: the National Alliance for Public Charter Schools reports a net increase of 381 charters operating between Fall 2011 and Fall 2012, with a charter enrollment gain of 13.5 percent. Growth has been especially strong in large urban districts such as Boston, Los Angeles, Newark, New York, Oakland, and Philadelphia, where many students are poor and most are nonwhite. The schools in these districts are often described as low-performing, with low standardized test scores, high truancy rates, and high dropout rates.¹

In the 2014-15 school year, the New Orleans Recovery School District (RSD) became America's first all-charter public school district. RSD emerged from a 2003 effort to improve underperforming public schools in New Orleans, home to some of the worst schools in the country. State legislation known as Act 9 allowed the Louisiana Department of Education (LDE) to take control of, manage, and outsource the operation of schools deemed low-performing based on measures related to achievement, attendance, and graduation rates. As a result of Act 9, New Orleans public schools that came under state control became part of RSD, while other schools remained under the authority of the Orleans Parish School Board (OPSB).²

Hurricane Katrina, which decimated New Orleans public schools in August 2005 along with the rest of the city's infrastructure, was a watershed event in the history of RSD. Among other disruptions caused by the hurricane, many public schools closed and enrollment plummeted.³ The scramble to reopen New Orleans schools prompted further legislative action in November of 2005. Louisiana's Act 35 allowed RSD to assume control of 114 low-performing New Orleans schools, leaving OPSB with authority over only 17 of the schools it ran before Katrina.

¹See NCES (2013) for national enrollment statistics by school type and NACPS (2013a) for statistics on charter growth. The latter report notes 531 new charters schools opened and 150 charter schools closed. CREDO (2013a) compares the demographic characteristics of traditional public and charter school students; NACPS (2013b) gives statistics on charter shares by district.

²Cowen (2011c) gives a history of RSD.

³See Vigdor (2007), Groen and Polivka (2008), Sacerdote (2012), Imberman et al. (2012), and Deryugina et al. (2014) for analyses of the effects of Katrina on outcomes related to education and the labor market.

In the following years, as enrollment grew from the immediate post-Katrina trough, both RSD and OPSB converted increasing numbers of low-performing schools to charters. By Fall 2008, when combined RSD and OPSB enrollment had reached 36,000 (just over half of pre-Katrina OPSB enrollment), the much-reduced OPSB district had 73% of its students in charters, while the RSD charter share hit 49%. Since 2008, RSD charter growth has accelerated, and September 2014 saw the closure of the few remaining direct-run traditional public schools in RSD (OPSB continues to operate a mix of traditional and charter schools). The 2008 school year also marked the beginning of a period of relative stability in RSD enrollment, leadership, and finances, along with district-wide improvements in achievement. RSD achievement gains – in both direct-run and charter schools – can be seen in Figure 1, which compares post-2008 math achievement trends in RSD, OPSB, and the rest of Louisiana (ELA trends are virtually identical). Average achievement for traditional and RSD charter students runs mostly below the statewide and OPSB averages, but the gap was much reduced by 2014.

A distinctive feature of New Orleans’ charter expansion is the fact that most of the RSD charter schools that have opened since 2008 are *takeovers*. A charter takeover occurs when an existing public school, including its facilities and staff, come under charter management. Importantly, takeovers guarantee seats for incumbent students, “grandfathering” these students into the new school. By contrast, most charter schools in other districts open as *startups*, that is, new schools (sometimes in existing school buildings), with no seats guaranteed by virtue of previous enrollment.

Boston’s experiment with charter takeovers has unfolded with less urgency than New Orleans’, but the forces behind it are similar. At the end of the 2010-2011 school year, nine schools in the Boston Public School (BPS) district were closed for persistently low performance. In an effort to turn two of these schools around, the UP Academy Charter School of Boston replaced the former Gavin middle school, while Boston Green Academy (BGA) replaced the former Odyssey high school, both in Fall 2011. These *in-district charter schools*, known in the state bureaucracy as Type-III Horace Mann schools, mark a new approach to charter authorization and school autonomy in Massachusetts. The Boston School Committee authorizes in-district charter schools and funds them through the BPS general budget like their predecessors. In-district charter teachers are also members of the Boston Teachers Union. Outside of pay and benefits, however, terms of the relevant collective bargaining agreements are waived and these schools are free to operate according to their charters. Boston’s in-district charters opened with new school leaders and new teaching staff, employed on an essentially at-will basis, while guaranteeing seats to students formerly at Gavin and Odyssey.⁴

⁴The charter schools studied in our earlier work using lotteries (Abdulkadiroğlu et al., 2011) are known as “Commonwealth charters.” Commonwealth charters are authorized by the state as startups and operate as independent school districts.

This paper evaluates the causal effects of RSD and Boston takeover schools on student achievement with an instrumental variables (IV) strategy that exploits the grandfathering provisions used to fill takeover seats. Grandfathering offers the opportunity to answer new questions about urban school reform. The growing set of econometric estimates exploiting charter school admissions lotteries, while consistently showing large gains for students at urban charters, necessarily captures causal effects only for charter applicants – a self-selected population that may be especially likely to see gains from the charter treatment.⁵ By contrast, grandfathered enrollment in charter takeovers is essentially passive: an existing population is guaranteed seats in the new school. Takeover experiments therefore identify causal effects on students who haven’t actively sought a charter seat. Grandfathering into takeover charters may also identify effects for schools with unusable or undersubscribed lotteries.

Our econometric strategy uses grandfathering eligibility to instrument takeover attendance in samples of public middle school students. The grandfathering identification strategy, while appealing on substantive grounds, raises two implementation issues. First, attendance at schools slated for closure (we refer to these as *legacy schools*) may have a direct effect on student achievement independent of subsequent matriculation at the takeover school. The trend in student achievement at closing schools in RSD suggests such violations of the exclusion restriction are indeed a concern. We therefore develop an estimation scheme that allows for distinct legacy school enrollment effects. A second concern is the heterogeneous nature of the takeover counterfactual, which mixes students at traditional public schools with students who enroll at non-takeover charters. This is especially important in RSD, which saw an increasing share of non-takeover charter enrollment over the study period. A simple two-stage least squares (2SLS) procedure addresses the problem of a mixed non-takeover counterfactual.

The empirical results reported here should be of immediate policy interest. The proliferation of traditional public schools that have been closed and reconstituted as charter schools reflects a federal push to encourage states to “require significant changes in schools that are chronically underperforming and aren’t getting better” (Duncan, 2010). The FY2011 federal budget operationalized this goal by adding three billion dollars to the roughly \$500 million previously appropriated for School Improvement Grants (SIGs). Federal SIGs, which offer up to two million dollars annually per qualifying school, support three restructuring models, one of which is the restart model, described as follows in USDOE (2009):

⁵Lottery estimates are reported in, e.g., Abdulkadiroğlu et al. (2011), Angrist et al. (2012), Angrist et al. (2013), Dobbie and Fryer (2011), Dobbie and Fryer (2013), Hoxby et al. (2009), and Tuttle et al. (2013). Ravitch (2010) (pp. 141-144) and Rothstein (2011) challenge the external validity of charter treatment effects estimated using lotteries. See also Rothstein’s account of high scores at KIPP: “They select from the top of the ability distribution those lower-class children with innate intelligence, well-motivated parents, or their own personal drives, and give these children educations they can use to succeed in life.” (Rothstein, 2004, p. 82.)

A restart model is one in which [a local education agency] converts a school or closes and reopens a school under a charter school operator, a charter management organization (CMO), or an education management organization (EMO) that has been selected through a rigorous review process. A restart model must enroll, within the grades it serves, any former student who wishes to attend the school.

The RSD and BPS charters studied here, which we refer to as “takeovers,” qualify for federal support as “restarts.”

The rest of the paper is organized as follows. Following a brief background discussion in Section 2, Section 3 explains the grandfathering identification strategy and shows how it accommodates possible violations of the exclusion restriction in our IV framework. Section 4 presents a detailed econometric analysis of charter takeovers in New Orleans RSD, and interprets these results against the backdrop of rising charter enrollment. Section 5 deploys the grandfathering research design in Boston, comparing grandfathering and lottery estimates of achievement effects at UP Academy. Gains for UP lottery compliers appear to be substantial, but gains for UP’s grandfathering compliers are at least as large. Finally, we look briefly at examples of an alternative school restructuring model in Boston, typically described as a “turnaround.” One of these was uniquely charter-like, replacing most staff with young outsiders much like those employed at UP and placing more emphasis on student monitoring, discipline, and comportment. Two other middle school turnarounds were more modest in scope and followed a more typical public school model. We find the first intervention to have produced gains as large as those seen at UP, while the other turnarounds’ effects appear much less impressive.

2 Background

2.1 Takeovers in New Orleans RSD

The RSD takeover explosion is documented in Figure 2. Of the RSD charters that have opened since Fall 2008 and were operating in Spring 2014 (excluding alternative schools that serve special populations), 21 are takeovers while 13 are startups. Even by the standards of the heated debate over school reform, the proliferation of charter takeovers in New Orleans and elsewhere has proven to be especially controversial.⁶ At the same time, the perception that RSD’s takeover policy has

⁶See, for example, Darling-Hammond (2012), who writes “In the new vision for ESEA, these schools, once identified, will be subjected to school ‘turnaround’ models that require the schools to be closed, turned into charters, reconstituted ... These approaches have a dubious track record. Many reconstitutions—where staff are fired and replaced—have resulted in a less qualified teaching staff and lower achievement after the reform.” A February 2014 civil rights complaint lodged with the US Department of Education’s Office of Civil Rights alleges closure of the final five traditional public schools in RSD has hurt the mostly African American students who attended these schools, a complaint that is now under review

been fruitful has prompted ongoing explorations of similar approaches in Michigan, Pennsylvania, and Tennessee.

Appendix Table A1 lists the 18 New Orleans RSD schools that experienced what the district calls a *full charter takeover* between the Fall 2008 and Fall 2013. Full takeovers convert all grades in the legacy school in a single academic year; the takeover school grandfathers legacy students in the relevant grades, and typically opens in the legacy school building.⁷ Alternatives to the full takeover model include principal-led conversions and school mergers. We focus on full takeovers because this intervention is broad and well-defined, with a clearly identified grandfathering cohort at the relevant legacy school. Five of the full takeovers examined here are conversions of existing charter schools and are therefore omitted from our study, which focuses on charter effects for students unlikely to enroll in a charter without a takeover. The two high schools in the table are also omitted; our analysis focuses on schools with middle school grades (in RSD, these are almost all K-8 schools) because this is where takeovers are most common and because the legacy school scores used to adjust for violations of the exclusion restriction are only available for middle schoolers.⁸

The decision to effect a full takeover at a low-performing RSD school was driven in part by average test scores and in part by the availability of a charter operator who met RSD qualifications for school management. Operators typically applied for a charter early in the legacy year, with some indicating a preference for specific school buildings. RSD decisions to implement a takeover were usually announced no earlier than December of the legacy year, with the charter operator announced between January and May. School Performance Scores (SPS), a test score metric discussed in detail below, were often considered in takeover decisions, but legacy schools are not typically the lowest-performing in the district. For example, the five takeovers initiated in 2010 saw an average SPS score of 49.4 in the previous year, quite representative of the RSD direct-run average of 50.9. As discussed below, we leverage the existence of many similarly low-performing direct-run schools, operating alongside legacy schools but not yet closed or converted to a charter, for our matching-based research design.⁹

(Drellinger, 2014).

⁷With the advent of OneApp in 2012, grandfathering-eligible students who wanted a takeover seat needed only indicate their desire to return to their current school on RSD's common application.

⁸Louisiana issues five types of charters, according to whether the school is authorized by the local school board or the LDE, whether the school is new or a conversion, and whether the school is in RSD. RSD's Type 5 charter schools, the focus of our study, are authorized and overseen by the LDE. The takeover/startup distinction is less clear in OPSB than in RSD. Of the 14 charters operating in OPSB in Fall 2013, three are startups and 11 were created in the immediate Katrina aftermath. Although these "Katrina takeovers" were tied to the closure of particular traditional schools, and admissions policies at the new schools reference preferences for those who attended the schools they replaced, for the most part they do not appear to have guaranteed seats to these students. In contrast with RSD charters, four OPSB charters have selective admissions policies.

⁹Among these comparison schools, most were closed outright in the lead-up to RSD's full charter conversion, though a few saw principal-led conversions or grade-by-grade mergers with an existing charter operator instead.

Table A1 shows that the 11 legacy schools in our study were taken over by six charter management organizations (CMOs), with the Crescent City and ReNEW CMOs each operating multiple schools. In two cases in 2013, two legacy schools were merged into a single takeover school. Table A1 also shows that 7 out of 9 study takeover schools were operated by CMOs that describe themselves as embracing No Excuses pedagogy.¹⁰ The No Excuses model for urban education – sometimes also called “high expectations” – is characterized by extensive use of tutoring and targeted remedial support, reliance on data and teacher feedback, a curriculum focused on basic skills, high expectations from students and staff, and an emphasis on discipline and student comportment.

RSD’s charter schools function outside the collective bargaining agreement between OPSB and the union (United Teachers of New Orleans) that represents teachers at non-charter OPSB schools and a few OPSB charters (Cowen, 2011c). Appendix Table A2 compares teacher characteristics at RSD direct-run and charter schools. Teachers at RSD charters tend to have less experience and earn lower base salaries than those at direct-run schools. Class sizes at takeover and legacy schools are similar and close to those seen at other charter and direct-run public schools. Per pupil expenditure is somewhat lower at RSD charter schools, though this may reflect compositional differences in the student body and the experience distribution among teaching staff. The PPE contrast between takeover and legacy schools shows only a small gap.¹¹

2.2 UP from Gavin Middle School

Our Boston analysis focuses on the UP Academy Charter School of Boston, the middle school in the pair of original Boston in-district charters. The UP Education Network (formerly known as Unlocking Potential) is rapidly expanding, having recently assumed responsibility for management of two schools in Boston’s Dorchester neighborhood (one elementary and one K-8), and opened two (non-charter) middle schools in Lawrence, Massachusetts. Our middle school focus necessarily excludes BGA, Boston’s in-district charter high school. In this context, it’s worth noting that BGA is more of an in-district conversion than a takeover, since it was initially staffed by BPS teachers and administrators from elsewhere in the district.¹²

¹⁰An online appendix table lists our sources for this classification. See http://seii.mit.edu/wp-content/uploads/2015/04/ID_onlineappendix_03122015.pdf

¹¹RSD schools, both direct-run and charter, are funded from local and state taxes using a formula that allocates funding by enrollment. Federal grants (such as Title I funds) flow to direct-run schools through RSD and to charters through their CMOs (Cowen, 2011a). Unlike direct-run schools, charter schools can save unspent funds from one year for use in another (Cowen, 2011b).

¹²BGA’s founding headmaster and chairman of the board came from Boston Fenway High School, a pilot school (see Abdulkadiroğlu et al. (2011) for an evaluation of Boston’s pilot schools). Concerns about poor record-keeping and continued low performance at the school recently prompted the state commissioner of education to recommend that BGA be put on probation for the remainder of its charter (Vaznis, 2014).

Boston’s in-district model arose in the wake of a 2010 Massachusetts law that allowed BPS to open up to four charter schools without union approval. The in-district model was one of a number of policy experiments hoped to quickly improve schools with persistently low performance.¹³ As in RSD, the birth of an in-district charter reflects both the district’s desire to address low school performance and the presence of a willing operator: UP Education Network was selected as an in-district operator partly because it was ready to grandfather all Gavin students (Toness, 2010). Gavin students were automatically admitted to UP Boston, though a simple application was required (UP staff visited Gavin students’ homes to encourage application).¹⁴

Unlike other charter schools in Boston, which operate as independent districts and are funded by inter-district transfers, UP spending appears in the BPS budget. Former Gavin teachers were free to apply for positions at UP, and a handful did so, but their positions were not grandfathered and, according to school officials, none were ultimately hired to work at UP. UP administrators and staff are part of the collective bargaining units representing other BPS workers, but the school functions in a looser framework established in memoranda between UP and the district. UP is required to pay collectively bargained wage rates (or more), but school leaders and UP administrators make personnel decisions freely, as in a non-union workplace.

As can be seen in column 8 of Table A2, which also compares teacher characteristics at the Boston schools in our study, UP’s teachers in our sample period are much younger than was the Gavin staff: 60 percent of UP’s teachers are no older than 28, This is unusually youthful even by the standards of Boston’s other charter schools. UP class sizes are smaller and per-pupil expenditure is somewhat lower than at the Gavin school. Like most of our RSD schools, UP’s charter aligns the school with the No Excuses model.¹⁵ The UP school day is two hours longer than the Gavin day had been and UP teachers are expected to report for work each year on August 1.

¹³Gavin and Odyssey were ranked at the bottom of a list of low-performing schools in 2010, by some measures the worst on the list. Yet for various reasons, these schools didn’t qualify for state designation as “Level 4.” In response to our queries, BPS administrators emphasized that in-district charter conversion was one of several strategies available to the district for schools designated Level 3.

¹⁴Some high needs special education students at Gavin were grandfathered into the Richard Murphy school, which operates a satellite program in the former Gavin building (BPS (2013), pp. 6 and 146). These cases notwithstanding, the overall UP enrollment take-up rate for grandfathered special education students is close to that for other grandfathered students. Our IV strategy treats all grandfathered students the same, and estimates conditioning on baseline special education status, though often imprecise, are qualitatively similar to those from the full sample.

¹⁵UP’s charter application states “all stakeholders should not make or accept excuses for anything less than excellence,” and describes key No Excuses practices as part of their educational programming (UP Academy, 2010). More recent school documents emphasize a culture of “high expectations.” (See, for example, <http://upeducationnetwork.org/all-about-up/>).

2.3 Related Research on Takeovers and Turnarounds

Dee (2012) uses the test proficiency cutoffs that determine qualification for federal SIG funding in a regression discontinuity study of the causal effects of SIG awards. Dee’s estimates suggest that SIG-funded interventions improve performance for students at treated schools. His companion difference-in-differences analysis points to the intermediate federal turnaround model as the most effective, while estimates for the remaining two SIG strategies, including restarts, are not significantly different from zero. It’s worth noting, however, that very few California schools opted for the more radical restart intervention, and Dee’s estimates for the restart treatment are correspondingly imprecise.

Houston’s pioneering Apollo 20 program revamped educational practices along No Excuses’ lines in 20 of Houston’s lowest performing schools, while replacing most school leaders and half of the teaching staff in these schools; a similar effort was undertaken on a smaller scale in Denver. The insertion of charter school best practices in existing public schools provides a natural alternative to the takeover model studied here, and qualifies for the same sort of federal support. The cluster-randomized trial and quasi-experimental analyses of the Apollo makeovers in Fryer (2014) show statistically significant gains in math of between one-fifth and one-sixth of a standard deviation, with little effect on reading. Fryer’s quasi-experimental analysis uses baseline enrollment zones to construct instruments for exposure to treatment. Our grandfathering strategy similarly uses a baseline condition to isolate exogenous variation, but the approach here incorporates matching on baseline school characteristics to eliminate covariate differences associated with the grandfathering instrument. Our IV identification strategy also allows for violations of the exclusion restriction that may compromise naive grandfathering estimates.¹⁶

In a recent report, CREDO (2013b) uses a variety of comparison methods to evaluate the effects of attending three RSD takeover charters. The CREDO study presents a fine-grained analysis that distinguishes many types of students based on their baseline and post-takeover enrollment status, comparing, for example, students who move into and who exit from schools slated for charter conversion. This analysis generates a complicated picture of mixed positive and negative effects, though these sorts of comparisons do not appear to fit into a causal framework except under much stronger conditional independence assumptions than those invoked here. At the same time, CREDO (2015) reports modest gains from the New Orleans charter sector as a whole in their national matched-pair study of urban charter school effectiveness. In contrast, the grandfathering IV methodology developed

¹⁶In a methodologically related study, Jacob (2004) also uses an initial condition – whether a student resides in a public housing building later slated for demolition – as an instrument for the effect of public housing on children’s achievement. Our framework clarifies the formal assumptions needed and highlights the specific identification possibilities in this and similar grandfathering IV strategies.

here can directly test whether charters benefit the subpopulation of students that enroll passively, a question not addressed by observational charter school studies such as CREDO (2015).¹⁷

3 Grandfathering Identification

3.1 The RSD Comparison Group

Our grandfathering research design uses a combination of matching and regression to mitigate omitted-variables bias in comparisons of grandfathering-eligible and ineligible students. To see how the matched comparison group is constructed, consider the set of 6th graders enrolling at an RSD school slated for takeover at year’s end: 6th grade legacy school enrollment entitles this group to 7th grade seats in the takeover charter. Since legacy and takeover schools in RSD typically enroll grades K-8, there are few non-legacy 6th graders who share a 5th grade school with the grandfathering-eligible group. We therefore look for a comparison group in the population of 6th graders not enrolled at the legacy school, but who attended schools similar to those attended by legacy school students in 5th grade (we refer to these as *baseline schools*). Specifically, baseline schools are matched if they have School Performance Scores (SPS) in the same five-point bin.¹⁸ In addition to baseline schools, we construct the RSD comparison sample by matching grandfathering-eligible and ineligible students on race, sex, baseline year, baseline special education status, and baseline subsidized lunch eligibility.

In practice, the RSD grandfathering experiment involves multiple grades, schools, and years. The relationship between legacy grades, baseline grades, and takeover grades in each RSD grandfathering scenario is described in Table 1. Because the earliest available baseline information is from 3rd grade, our RSD sample covers legacy school enrollment in grades 4-7 and takeover charter enrollment in grades 5-8. Potential takeover exposure thus ranges from one year (for students in 7th grade in the legacy year) to four years (for students in 4th grade in the legacy year), or more if grades are repeated. A given matching cell may contain students who were eligible for grandfathering into multiple takeover charters; the grandfathering instrument indicates eligibility at any of the 9 takeover schools we study. When pooling across grades, we retain students in the first year they become or are matched to a grandfathering-eligible student. The number of grandfathering-eligible students enrolled in a legacy school in the fall of the year prior to takeover averages roughly 70 students per school and is about

¹⁷See also McEachin et al. (2014) for an observational analysis of the New Orleans charter school sector that does not distinguish between passively-enrolled takeover students and charter lottery winners.

¹⁸SPS scores are used for accountability purposes within RSD. Until academic year 2011-2012 (the last baseline year for our sample of RSD takeovers), SPS scores ranged from 0 to 200, and have since transitioned to a 0-150 scale. Our results are virtually unchanged when smaller bins are used; bins wider than about 10 points generate a coarse match with many low-scoring schools grouped together.

one-third the size of the matched comparison group (Appendix Table A3 reports the number of observations contributed by each RSD legacy school).

Our primary analysis outcomes in RSD are Math and English Language Arts (ELA) standardized test scores, measured by the Louisiana Educational Assessment Program (LEAP) in 4th and 8th grade and the Integrated Louisiana Educational Assessment Program (iLEAP) in grades 5-7, from Spring 2011 (the first exposure Spring of the first takeovers in our sample) through 2014.¹⁹ The Data Appendix details the construction of our analysis files from raw student enrollment, demographic, and outcome data. For the purposes of statistical analyses, scores are standardized to the population of RSD test-takers in the relevant subject, grade, and year (excluding students in alternative programs).

Table 2 reports descriptive statistics for the RSD analysis sample and for broader samples of RSD students with the same distribution of baseline grades and years. As can be seen in the first two columns of the table, almost all RSD and RSD charter-bound students (those enrolled in an RSD charter school in the grades following baseline) are black, and most are poor enough to qualify for a subsidized school lunch. RSD charter-bound students have baseline scores near the overall district mean (zero, by construction). By contrast, students who enroll in takeover charters and those eligible for grandfathering have much lower baseline test scores. For example, the average baseline math score of grandfathering-eligible students in our analysis sample is around 0.27σ below the corresponding RSD population average. This marks an important contrast with baseline achievement in samples of lottery applicants at many oversubscribed charter schools, a group that tends to be positively selected on baseline characteristics.²⁰

The RSD comparison group appears to be well-matched to the RSD grandfathering cohort. This is documented in column 5 of Table 2, which reports regression-adjusted differences in variables not used for matching between grandfathering-eligible students and the matched comparison group. The balance coefficients come from a model that includes a full set of matching-cell fixed effects, with no further controls. These estimates show no statistically significant differences in the limited English proficiency rates or in baseline scores (balance here is primarily achieved by controlling for baseline school SPS bins).

Appendix Table A4 reports follow-up rates and gauges differential attrition in the RSD analysis sample. Follow-up scores are available for almost three-quarters of students in the first two years

¹⁹LEAP and iLEAP include multiple-choice and open-answer questions. LEAP scores are used for determining grade-progression according to Louisiana state guidelines. The iLEAP test combines a test of academic standards and a norm-referenced component from the Iowa Test of Basic Skills (ITBS) through 2012-2013. The 2013-2014 iLEAP tests no longer contain the ITBS portion.

²⁰In the middle school sample analyzed in Abdulkadiroğlu et al. (2011), for example, the baseline math gap between charter applicants and Boston students is around 0.36σ .

following a takeover. The follow-up rate declines markedly in years three and four, reflecting RSD’s highly mobile low-income population, a pattern seen in other urban high-poverty districts. Importantly, however, the likelihood an RSD student contributes an outcome score to the analysis sample is unrelated to his or her grandfathering eligibility status, and, as shown in column 6 of Table 2, baseline covariates remain balanced in the analysis subsample for which we can measure outcomes.

3.2 RSD Grandfathering Graphics

We motivate the grandfathering identification strategy for RSD with a graphical comparison of achievement trends in the grandfathering-eligible and matched comparison samples. Provided scores in the eligible cohort and the comparison group move in parallel in the pre-takeover period, differences in score growth between eligible and ineligible students in the post-takeover period offer compelling evidence of a takeover treatment effect. As in Table 2, we regression-adjust these trends by matching-cell fixed effects, with no further controls.

The upper panels of Figure 3 show remarkably similar pre-takeover trajectories for the math and ELA scores of grandfathering-eligible and ineligible students. The data plotted here are standardized to samples of students at RSD’s direct-run schools, so that achievement trends are cast relative to this group. Consistent with RSD’s focus on low-performing schools when assigning takeovers, relative achievement at legacy schools declines in the grade before takeover, though the broader comparison group trend is essentially flat (for ELA) or generally increasing (for math). Importantly, the pre-takeover dip (reminiscent of the pre-treatment earnings dip documented by Ashenfelter (1978) for applicants to job training programs) is mirrored in the matched comparison group.

Matching effectively eliminates baseline differences by grandfathering status, so that simple post-treatment comparisons seem likely to reveal causal effects. We nevertheless present difference-in-differences (DD) style comparisons of achievement growth, a natural econometric starting point. These comparisons appear in the lower panels of Figure 3, which plot achievement growth in the grandfathering-eligible and ineligible subsamples relative to the baseline grade. Pre-baseline growth differences by grandfathering status are centered around zero, while achievement contrasts after the legacy year strongly favor the grandfathered cohort. Since around 66% of students matriculate at a takeover charter when becoming eligible for grandfathering (a figure reported in Table 3, discussed below), this pattern suggests takeover enrollment significantly boosts achievement.

Figure 3b shows remarkable parallelism in pre-takeover score trends up to, but not including, the year of legacy enrollment. The negative and significant (for math) DD contrast in the legacy year signals a possible causal effect of legacy enrollment *per se*, regardless of whether legacy attendance leads

to subsequent enrollment in the takeover charter. This is an unsurprising but potentially important finding: legacy schools were slated for closure in part because of extraordinarily low and even declining achievement and the act of closure itself could be disruptive, facts that may have lasting consequences for legacy students. Our grandfathering IV strategy therefore allows for direct effects of legacy school attendance when using legacy enrollment to instrument takeover attendance.

3.3 Econometric Framework

The grandfathering IV estimator contrasts legacy-to-post-takeover achievement growth by grandfathering status, scaled by differences in takeover enrollment rates. To interpret this procedure, consider a group of legacy school students and their matched comparison counterparts with covariate values falling in a single matching stratum. Achievement for each student is observed in two grades: at the end of the legacy grade, immediately prior to the takeover (grade l) and after the takeover (grade g). The grandfathering-eligible group is mostly enrolled in the takeover school in grade g , while few in the comparison group are. A dummy variable denoted by Z – the grandfathering instrument – indicates legacy school enrollment in grade l (observed at the start of the school year) while the variable D indicates takeover school enrollment at any time in grade g . Achievement in the two grades is denoted Y^l and Y^g , observed at the conclusion of the school year.

Legacy school enrollment in grade l potentially affects grade g achievement through two channels: by increasing the likelihood of takeover attendance in grade g and by adding a year’s exposure to the legacy school in grade l , an event that may have lasting consequences if learning is cumulative. Potential outcomes in grade g are therefore double-indexed. Specifically, we write Y_{zd}^g to indicate the grade g outcome that would be observed when $Z = z$ and when $D = d$. Potential outcomes in grade l , written Y_z^l , are indexed against Z alone, since grade l predates takeover exposure. Using the potential treatments notation of Imbens and Angrist (1994), legacy enrollment shifts takeover exposure from D_0 to D_1 . In this setup, observed outcomes are determined by potential outcomes and by the instrument as follows:

$$\begin{aligned}
 Y^l &= Y_0^l + Z(Y_1^l - Y_0^l), \\
 D &= D_0 + Z(D_1 - D_0), \\
 Y^g &= Y_{00}^g + Z(Y_{10}^g - Y_{00}^g) + D(Y_{01}^g - Y_{00}^g + Z(Y_{11}^g - Y_{10}^g - (Y_{01}^g - Y_{00}^g))) \\
 &= Y_{00}^g + Z(Y_{10}^g - Y_{00}^g) + (D_0 + Z(D_1 - D_0))(Y_{01}^g - Y_{00}^g + Z(Y_{11}^g - Y_{10}^g - (Y_{01}^g - Y_{00}^g))),
 \end{aligned}$$

where the last line uses the expression for D to obtain a representation for observed Y^g as a function of potential outcomes, potential treatments, and the instrument Z .

Potential outcomes and treatments are assumed to satisfy the following canonical assumptions:

Assumption 1 (*Independence*) $\{Y_0^l, Y_1^l, Y_{00}^g, Y_{01}^g, Y_{10}^g, Y_{11}^g, D_0, D_1\} \perp\!\!\!\perp Z$.

Assumption 2 (*Monotonicity*) $Pr(D_1 \geq D_0) = 1$.

Assumption 3 (*First-stage*) $E[D_1 - D_0] > 0$.

Assumption 1 – Independence – asserts that the grandfathering instrument is as good as randomly assigned with respect to potential outcomes and treatment take-up (implicitly, within matching strata). Table 2 and Figure 3, which show that matching eliminates covariate and baseline score differences in our RSD analysis sample, support this. Monotonicity says that legacy enrollment either induces takeover enrollment or has no effect for all individuals in the analysis sample. Assumption 3 requires legacy enrollment to induce takeover enrollment, at least for some.

As in the Angrist et al. (1996) framework for identification of local average treatment effects (LATE) with possible violations of the exclusion restriction, Assumptions 1-3 allow for direct effects of legacy exposure on grade g outcomes. Such effects arise if

$$Y_{1d}^g \neq Y_{0d}^g,$$

when D is fixed at d . In other words, maintaining the assumption that legacy enrollment is as good as randomly assigned, we've allowed for violations of the exclusion restriction associated with use of Z as an instrument for D . In view of the comparatively low achievement seen at the legacy school and the explicit link between legacy attendance and the grandfathering instrument, the possibility of such violations seems inherent in the grandfathering research design.

Rather than defend a conventional exclusion restriction in this setting, we replace it with a closely related but weaker restriction on potential achievement *gains*. This allows for direct additive effects of legacy enrollment that are free to vary within the LATE subpopulations of always-takers (those with $D_1 = D_0 = 1$), never-takers (those with $D_1 = D_0 = 0$), and compliers (those with $D_1 > D_0$):

Assumption 4 (*Gains Exclusion*) $E[Y_{1d}^g - Y_1^l | T] = E[Y_{0d}^g - Y_0^l | T]$, where $T = aD_0 + n(1 - D_1) + c(D_1 - D_0)$ identifies always-takers (a), never-takers (n), and compliers (c).

Assumption 4 requires that expected potential achievement gains be the same for those who do and don't attend the legacy school in grade l , once takeover enrollment is fixed. This allows $Y_{1d}^g \neq Y_{0d}^g$, while also weakening the canonical exclusion restriction applied to gains, which says that $Y_{1d}^g - Y_1^l = Y_{0d}^g - Y_0^l$ for everyone, rather than just on average. Balance in pre-baseline to baseline score gains by

grandfathering eligibility status – documented for the RSD matched sample in Table 2 – is an indirect test of this assumption.

We can interpret Assumption 4 as the consequence of an additive structure for expected potential outcomes in each grade:

$$(1) \quad E[Y_z^l | T = s] = \alpha_{1s} + z\gamma_s$$

$$(2) \quad E[Y_{zd}^g | T = s] = \alpha_{2s} + z\gamma_s + d\beta_s.$$

The parameters α_{1s} and α_{2s} in these expressions are subgroup-specific potential outcome means with both the legacy- and takeover-enrollment indicators switched off; γ_s is an additive legacy school enrollment effect, common to grades l and g ; and β_s is the causal effect of takeover attendance for LATE subgroup s . This additive model rules out interactions between legacy and takeover attendance, while allowing legacy effects to persist across grades.

The appendix shows that under Assumptions 1-4, a Wald-type IV estimator applied to achievement gains captures the average causal effects of takeover attendance on compliers' grade g achievement as follows:

Theorem 1 Under Assumptions 1-4,

$$\frac{E[Y^g - Y^l | Z = 1] - E[Y^g - Y^l | Z = 0]}{E[D | Z = 1] - E[D | Z = 0]} = E[Y_{11}^g - Y_{10}^g | D_1 > D_0] = E[Y_{01}^g - Y_{00}^g | D_1 > D_0].$$

Proof: See appendix.

This theorem identifies average causal effects of takeover exposure on test score *levels*, notwithstanding violations of the exclusion restriction due to legacy school enrollment (in the notation of equations (1) and (2), the theorem yields identification of β_c).

We use the logic of Theorem 1 in two ways: to capture causal effects of takeover enrollment in the year following a takeover and to capture causal effects of an ordered treatment that counts years of takeover exposure. The latter is supported by a similar result detailed in the appendix, which shows how the IV estimand for an ordered treatment can be interpreted as a convex combination of incremental average causal effects. To explore the robustness of our conclusions to Assumption 4, the econometric appendix also discusses models and estimates that allow legacy school effects in the takeover grade to only be partially carried over from the legacy grade.

Motivated by these theoretical results, we estimate the causal effects of takeover attendance with a second-stage estimating equation that can be written

$$(3) \quad Y_{it}^g - Y_i^l = \alpha' X_{it} + \sum_j \kappa_j d_{ij} + \beta D_{it} + \eta_{it},$$

where Y_{it}^g is student i 's score in year t in grade g and Y_i^l is i 's score in the last grade in which he or she was potentially enrolled in the legacy school. The treatment variable here, D_{it} , counts the number of years student i spent at the takeover school as of year t , up to and including the grade enrolled in that year (D_{it} is Bernoulli for tests taken in the first year of takeover operation).

The first stage equation that accompanies this second stage is

$$(4) \quad D_{it} = \delta' X_{it} + \sum_j \mu_j d_{ij} + \pi Z_i + \nu_{it},$$

where Z_i is the excluded instrument, an indicator of legacy enrollment in the fall of the legacy school's final year in operation, and π is the associated first stage coefficient. As with the models used to investigate covariate balance, equations (3) and (4) control for matching cell fixed effects. In particular, because the comparison sample consists of an exact match on race, sex, baseline special education status, baseline subsidized lunch eligibility, baseline school, baseline year, and the legacy grade, equations (3) and (4) include dummies for each of these cells, denoted d_{ij} for cell j . The empirical first- and second-stage models also include dummies for English proficiency and year-of-test (denoted by the vector X_{it} , with coefficients α and δ). Finally, although baseline score controls appear to be uncorrelated with grandfathering exposure in RSD, X_{it} includes these score controls to boost the precision of our estimates.

4 Charters without Lotteries in New Orleans RSD

4.1 Grandfathering Results

Attendance at RSD takeover charters increases math and ELA scores by an average of 0.21σ and 0.14σ , respectively, per year enrolled. These IV estimates, reported in the last column of Table 3, are generated by a first stage of about 1.1 years of takeover exposure (first stage estimates are reported in column 3). The associated robust standard errors are on the order of 0.04.²¹ Analyses that disaggregate by outcome grade and by years of potential takeover exposure show that takeover effects are larger in 7th and 8th grade than earlier, and are larger in the first two years of takeover exposure than later. The first stage effect of grandfathering eligibility on enrollment in the first exposure year, reported at the top of panel C, reveals that grandfathering boosted initial takeover enrollment rates by around 66 percentage points.

The IV estimates generated by the grandfathering design exceed (and, in many cases, are signifi-

²¹Estimates of effects on science and social science are similar, and are reported in the online appendix. See http://seii.mit.edu/wp-content/uploads/2015/04/ID_onlineappendix_03122015.pdf.

cantly different from) the corresponding OLS estimates reported in column 2 of Table 3. This suggests that uninstrumented comparisons by takeover enrollment status, such as those reported in CREDO (2013b), reflect substantial negative selection bias. It’s also worth noting that IV estimates that fail to adjust for legacy enrollment, such as those reported in Fryer (2014), would appear to be biased downwards. Fitting versions of equations (3) and (4) to post-treatment levels rather than gains generates math and ELA effects of 0.16σ and 0.11σ , respectively. Differences between these estimates and those for gains are consistent with the negative legacy-year treatment effects suggested by Figures 3 and 4. Appendix Table A9 reports legacy year treatment effects and estimates of models that weaken Assumption A4 to allow for partial pass-through of legacy effects – these estimates are very much in-line with those reported in Table 3 (see the econometric appendix for details on this procedure).

4.2 Interpreting RSD Takeover Effects

The RSD grandfathering identification strategy compares students that mostly attend takeover charters with a grandfathering-ineligible comparison group that went to various sorts of schools. Most students in the comparison group began middle school at one of RSD’s direct-run public schools. But the distribution of takeover alternatives evolved as RSD closed its direct-run schools and as students changed schools for reasons other than closure. Estimates of RSD takeover effects therefore reflect a growing share of charter-to-charter comparisons. If *all* RSD charters boost student achievement, such comparisons mask a higher overall charter treatment effect.

Table 4 describes the grandfathering attendance counterfactual in detail, focusing on the distinction between the charters that define the takeover treatment for the purposes of Table 3 (“study takeovers”), other takeover schools (including charter-to-charter conversions), non-takeover RSD charters, and direct-run RSD schools. Specifically, the first two columns show the distribution of school types by grandfathering status, while column 3 describes the types of schools attended by untreated compliers. These complier attendance counterfactuals are constructed by estimating causal effects of the takeover enrollment dummy, D , on school sector indicators, W . Associated with each W are potential attendance outcomes, W_0 and W_1 , describing school choices in non-treated and treated states (that is, potential school type when $D = 0$ and $D = 1$). Column 3 of Table 4 reports estimates of $E[W_0|D_1 > D_0]$, the distribution of school types among compliers when they do not enroll in a takeover, estimated using the weighting procedure derived by Abadie (2003).²² By definition, treated

²²The weights in this case are given by $\kappa_0 = (1 - D) \frac{E[Z|X] - Z}{E[Z|X](1 - E[Z|X])}$. We estimate $E[Z|X]$ by a probit model with the same covariate specification used to construct the estimates in Table 3. See Table 1 in Abdulkadiroğlu et al. (2014a) for a similar analysis of school choice in a sample of applicants to Boston and New York exam schools.

compliers enroll in a takeover school when they're grandfathering-eligible; column 4 in the table is included as a reminder of this fact.

The first stage for enrollment in a study takeover contrasts a 78 percent first-year takeover enrollment rate for those grandfathered (reported in column 2 of Table 4) with an 8.9 percent comparison group enrollment rate (reported in column 1). The first-year increase in (study) takeover enrollment reflects a substantial reduction in rates of attendance at non-takeover charters (compare 33 with 15) and, especially, a sharp reduction in attendance at direct-run schools (compare 51 with 3.4). The counterfactual attendance distribution in column 3 shows that 32 percent of untreated compliers enrolled initially in a non-takeover charter school, while 60 percent attended a direct-run school.

Not surprisingly, both the takeover first stage and the proportion of the comparison group in direct-run schools falls over time. The (study) takeover first stage in the third year of exposure is around 0.48 (0.754-0.277), while the counterfactual direct-run enrollment share falls to about 0.27. The balance of third-year non-treated complier enrollment was in other RSD charter schools. Reflecting RSD's accelerating charter transformation, the other-charter enrollment rate for compliers in our sample exceeded 86 percent after four years of exposure.

The growing share of the RSD comparison sample enrolled in charter schools dilutes estimated takeover effects if other charter schools generate similar gains. This motivates a 2SLS model with two endogenous variables, one tracking study takeover attendance and one tracking attendance at other sorts of charters. The model with two types of treatments can be written

$$(5) \quad Y_{it}^g - Y_i^l = \alpha' X_{it} + \sum_j \kappa_j d_{ij} + \beta_D D_{it} + \beta_C C_{it} + \eta_{it},$$

where C_{it} counts the number of years of attendance in charters other than those covered by D_{it} prior to testing. Equation (5) is identified by adding interactions between the grandfathering instrument and covariates to the instrument list (specifically, interactions with baseline year, special education status, and SPS five-point bins). These interactions generate a first stage for C_{it} because students with differing characteristics (covariate values) are more or less likely to wind up in non-takeover charters in the event they aren't grandfathered.

Removing other charters from the counterfactual outcome distribution with the aid of equation (5) nearly doubles the estimated takeover effect on math scores. This can be seen in the contrast between the estimates in columns 2 and 3 of Table 5. Column 1 repeats the takeover effect for the all-grades sample shown in Table 3, while column 2 reports an over-identified estimate of this effect with all instrument interactions, and column 3 reports 2SLS estimates of β_D and β_C . The takeover estimate for math in the latter specification rises to 0.36σ , while the other RSD charter effect is 0.32σ . These

results are quite similar to the estimates of math effects for Boston charter lottery applicants reported in Abdulkadiroğlu et al. (2011). On the other hand, the other-charter ELA effect in column 3 is close to zero. Consequently, the takeover effect on ELA scores remains near 0.14σ with or without a second endogenous variable to capture other-charter attendance effects.

The estimates in column 3 of Table 5 suggest takeover and other RSD charters have similar effects on math scores. We can therefore construct more precise estimates of this common charter effect by estimating a version of equation (5) that replaces $\beta_D D_{it} + \beta_C C_{it}$ with $\beta_A A_{it}$, where the variable $A_{it} = D_{it} + C_{it}$ counts years of attendance at any RSD charter. The resulting estimates of β_A , reported in columns 4 and 5 of Table 5 for just-identified and over-identified specifications, indeed show a precision gain, with standard errors falling from 0.073 and 0.152 in column 3 to 0.059 in column 5. The pooled specification for ELA generates a similar reduction in standard errors. It should be noted, however, that the divergence in estimated takeover and other-charter effects in column 3 make the pooled ELA results harder to interpret.²³

5 Measuring UP in Boston

Estimates from RSD suggest charter takeover attendance increased middle school achievement sharply. At the same time, RSD’s contemporaneous transformation to an all-charter district complicates the interpretation of RSD takeover effects. The 2011 takeover of Boston’s Gavin middle school affords another opportunity to measure charter takeover effects by the grandfathering research design, in this case against a more homogeneous and stable backdrop. The availability of over-subscribed admission lotteries at UP also allows a direct comparison of results from lottery and grandfathering research designs.

5.1 The UP Comparison Group

As in the analysis of RSD, we use a combination of regression and matching to reduce omitted-variables bias in grandfathering comparisons. Middle schoolers eligible for grandfathering into UP were enrolled at Gavin in 6th or 7th grade in the fall of 2010. Because both Gavin and UP serve grades 6-8, we can match each grandfathered student to the set of non-Gavin students who attended the same school in 5th grade. The Gavin comparison group consists of non-Gavin students matched on 5th grade school, and on race, sex, 5th grade special education status, and 5th grade subsidized lunch eligibility (Table

²³The common-effects model produces a weighted average of β_D and β_C , but the weighting scheme in this case need not be convex. The fact that the estimates in columns 4 and 5 exceed those in columns 1 and 3 reflect the negative weight this scheme assigns to the other-charter effect.

1 describes the timing of the grandfathering research design for UP). Each grandfathered student is again matched to one or more comparison students. The resulting analysis sample contains 290 grandfathering-eligible Gavin students, with 913 students in the comparison group; a total of 1,147 of these have baseline (5th grade) score data.

On-track 6th and 7th graders at Gavin transitioned to 7th and 8th grade when UP opened in Fall 2011. Achievement outcomes come from 7th and 8th grade Massachusetts Comprehensive Assessment System (MCAS) tests given in Spring 2012-2014. For the purposes of statistical analyses, MCAS scores were standardized to the population of BPS and Boston charter students from the relevant subject and year, excluding students in alternative schools.

Most BPS 5th graders are black or Hispanic, a fact documented in the first two columns of Table 6, which describes the population of Boston 5th graders in years covered by the UP analysis sample along with the subsample of Boston students headed for a charter middle school in grades 6-8. Like other charter students, those at UP or who were grandfathering-eligible are even more likely to be black, while Hispanics are under-represented in the charter-bound and grandfather-eligible groups. Almost all UP and grandfathering-eligible Gavin students qualify for a subsidized lunch. In contrast with the positive selection seen in the wider sample of charter-bound students in Table 6, those eligible for grandfathering into UP in the analysis sample have baseline scores well below those of students in the general BPS population.

The extent to which matching on baseline characteristics produces balanced grandfathering comparisons is explored in the last three columns of Table 6. The estimates in column 5 are from models that control only for matching cells; these show significant grandfathering gaps in baseline scores, suggesting the comparison group here is not as well-matched as for RSD. Importantly, however, the difference in baseline scores can be eliminated by conditioning on a further lagged score. The power of lagged score controls to produce balanced comparisons is illustrated in column 6 of the table, which shows the results of including fourth grade (pre-baseline) scores in the model used to construct the balance estimates. The addition of these controls eliminates the grandfathering gap in 5th grade scores. In other words, lagged score controls neutralize differences in measured achievement in a subsequent pre-takeover grade. All estimates of UP takeover effects thus control linearly for baseline achievement.

Follow-up scores are available for 80-90 percent of our grandfathering-eligible and matched comparison groups, a somewhat higher follow-up rate than for RSD over the same horizon. One year out, differences in follow-up between the grandfathered and comparison groups are small and not significantly different from zero when estimated with lagged baseline score controls, a result shown in Appendix Table A4. Follow-up differences are somewhat more pronounced for the cohort seen two

years out, though these differences are still only marginally significant. This modest difference in follow-up rates seems unlikely to account for the large score advantage our analysis uncovers for the grandfathered group, particularly in the first year of takeover.

5.2 UP Estimates

Achievement in the Gavin grandfathering cohort and the matched comparison group move largely in parallel in pre-takeover grades, diverging thereafter. This is apparent in Figure 4, which plots achievement paths in the same format used for RSD in Figure 3. 95% confidence bands for difference-in-differences comparisons are plotted with dotted lines in the bottom panel of these figures. The solid lines compare score growth in the grandfathered and comparison groups, relative to scores from the year preceding the last year of legacy enrollment. These DD estimates show marked and statistically significant differences in score growth in post-treatment years, with no significant differences earlier.

Interestingly, and in contrast with RSD, the Gavin experiment generates a positive DD estimate for legacy-year math scores (of about one tenth of a standard deviation). This result is marginally significant at best and may therefore be a chance finding. Taken at face value, however, this modest gain may reflect an effort by Gavin staff to improve outcomes in advance of – and perhaps in response to – the threat of school closure.

The UP enrollment change induced by grandfathering Gavin students boosted middle school math and ELA scores by an average of $0.3\sigma - 0.4\sigma$ per year. This can be seen in the pooled IV estimates of equation (3) reported in Panel A of Table 7. The first stage that generates these results is just over one, meaning on average grandfathering eligibility generated an additional year at UP. The first stage estimate from the first year of potential treatment, shown in Panel B, reveals the proportion of grandfathered 6th graders who remained at UP, around 80 percent. Math estimates by potential exposure are virtually identical, but the ELA estimate falls after the second year of exposure, from 0.5σ to 0.27σ . Given the exceptionally large first-year ELA impact this seems unsurprising, and is consistent with Figure 4’s difference-in-differences evidence for ELA, which shows a post-takeover achievement jump, followed by a plateau.²⁴

5.3 UP Lottery Estimates

Since the Fall of 2012, UP Academy, like other Boston charters, has filled its 6th grade seats through open lotteries, with priority going to current BPS students. Earlier, UP used lotteries to allocate seats

²⁴UP results without differencing post-takeover and legacy-grade scores are similar to those reported in Table 7, at 0.43σ for math and 0.24σ for ELA.

not taken by grandfathering-eligible students. A natural benchmark for the Gavin grandfathering strategy is the causal effect of charter attendance on UP students who participated in the lotteries used to fill the 7th grade seats not taken by former Gavin students in Fall 2011, and to fill all 6th grade seats then and since (few students apply for 8th grade seats at UP).

Our UP lottery sample includes applicants who applied for 6th grade seats in the school years beginning in Fall 2011 and Fall 2012, the first two years of UP operation, when we also measure outcomes for grandfathered cohorts. We also look at a smaller number of lottery applicants for 7th grade seats in 2011. Lotteries for other entry grades through Fall 2013 were not oversubscribed by first-round, non-sibling BPS applicants. Outcome data are from 6th-8th grade tests, taken in Spring 2012-2014. Baseline scores for the lottery sample are from 5th grade for applicants for 6th grade seats and from 6th grade for applicants for 7th grade seats. As with the grandfathering estimates, the lottery sample is limited to students who attend a BPS elementary school in the baseline grade. Appendix Table A5 gives an account of our lottery applicant data processing procedures.

Appendix Table A6 describes the UP lottery sample and documents baseline covariate balance by win/loss status. We construct two indicators for lotteried admission: an *initial offer* dummy indicates that a student was given an offer to attend on lottery night, while a *waitlist offer* indicator is switched on for students with the best randomly-ordered waitlist ranks (specifically, the waitlist instrument indicates applicants with lottery numbers below the highest number offered a seat in the relevant application cohort through September). This table also compares lottery applicants with the sample eligible for grandfathering into UP and with a general Boston sample that includes students in the same baseline grades and years attending BPS schools plus Boston charters (excluding those at alternative schools). In comparison to the Boston population, Black students are somewhat over-represented and Hispanic students somewhat under-represented among UP lottery applicants. Poverty rates, special education status, and limited English proficiency rates for lottery applicants are much like those seen elsewhere in Boston. Consistent with random assignment of lottery offers, the balance coefficients in columns 5-6 of Table A6 show UP lottery winners and losers are similar. Likewise, we see little evidence of excess loss to follow-up in the loser group.

Importantly, while UP lottery applicants' share many characteristics with the majority of Boston students in the same grade, and their baseline scores are not very different from the overall Boston mean, lottery applicants' baseline achievement far exceeds that in the grandfathering sample, which has baseline scores roughly a quarter of standard deviation below those for Boston. UP lottery applicants are also less likely than the grandfathered cohort to be poor enough to qualify for a subsidized lunch.

The lottery IV framework looks much like that described by equations (3) and (4) for grandfa-

thering instruments, with three modifications. First, there’s no matched comparison sample. Rather, the estimation sample consists of all lottery applicants, while the empirical models adjust for year and grade of application (that is, lottery “risk sets”) instead of matching cell fixed effects. Second, the dependent variable is the level of Y_{it}^g and not the gain relative to a legacy year, which is undefined for lottery applicants (to match the grandfathering specification, however, lottery estimates control for baseline scores). Finally, we use both lottery instruments. The lottery estimating equations can therefore be written

$$(6) \quad Y_{it}^g = \alpha' X_{it} + \sum_j \kappa_j d_{ij} + \beta D_{it} + \eta_{it}$$

$$(7) \quad D_{it} = \delta' X_{it} + \sum_j \mu_j d_{ij} + \pi_1 Z_{i1} + \pi_2 Z_{i2} + \nu_{it},$$

where Z_{i1} and Z_{i2} are the initial and waitlist offer instruments, dummies d_{ij} indicate lottery risk sets, and X_{it} is a vector of additional controls. The endogenous variable in this context counts years enrolled at UP between lottery application and the outcome test date.²⁵

The first stage effect of an immediate offer, close to 0.8 for the full sample, exceeds the first stage for waitlist offers, which is just under 0.6. These estimates appear at the top of columns 3 and 4 in Table 8. Looking at first stage effects in the first year of possible exposure to UP, we see that immediate and waitlist offers boost UP enrollment rates by 0.52 and 0.4, respectively. These estimates appear in the first row of panel B in Table 8. UP lottery applicants offered a seat in 6th and 7th grade admissions lotteries earned higher math and ELA scores as a result. Pooled 6th-8th grade 2SLS estimates, reported at the top of the last column of Table 8, show statistically significant average per-year score gains of 0.27σ in math and 0.12σ in ELA. Disaggregation by exposure time reveals larger average effects after one year than two.

The results in Tables 7 and 8 suggest that the benefits of UP enrollment for those enrolled there by virtue of grandfathering are at least as large as for UP students who won their seats in a lottery. The contrast in ELA estimates also favors grandfathering when we compare students who had equal exposure to UP: after one year, gains for the lottery cohort are 0.37σ in math and 0.22σ in ELA, while gains after one year for those grandfathered into UP come to 0.33σ in math and 0.5σ in ELA. Gains for the grandfathered cohort after two years of potential exposure are estimated to be 0.32σ in math and 0.27σ in ELA. This can be compared with estimated gains of 0.24σ in math and 0.08σ in ELA for similarly-exposed lottery cohorts.

²⁵In addition to lottery risk sets (application year and grade), our lottery analysis controls for student race, sex, special education status, limited English proficiency, subsidized lunch status, baseline test scores, and outcome year and grade effects. As with the grandfathering specification, additional baseline controls yield more precise and otherwise identical estimates.

As in our analysis of RSD takeover effects, an important consideration in this context is the type of school attended by compliers when not enrolling in UP. Differences in counterfactual school selection might account for the somewhat smaller achievement gains seen for lottery compliers; perhaps an especially large fraction of those not offered seats in UP lotteries wound up at other high-performing Boston charters, thereby diluting lottery-generated treatment effects.

Roughly 86 percent of untreated compliers in the grandfathering research design enrolled in a traditional BPS school, with 7 percent winding up in another Boston charter. This can be seen in Appendix Table A7, which details UP first stages and counterfactual school choices in the same format as Table 4 (likewise computed using the weighting formula in Abadie (2003)). By way of comparison, the lottery design leaves 94 percent of untreated compliers in a traditional BPS school, with only 6 percent in other charters. Counterfactual enrollment rates for both designs appear in column 3 of the table. The low proportion attending other charters, and the even smaller proportion at other charters among lottery compliers, imply that the excess of grandfathering over lottery estimates of UP attendance effects is not explained by a diluted counterfactual in the lottery control group. On the other hand, the fact that the grandfathered cohort has lower baseline scores than does the sample of lottery applicants probably contributes to the grandfathering-lottery impact gap. Elsewhere, we’ve found a consistently negative relationship between baseline achievement and charter score gains (Angrist et al., 2012, 2013).

5.4 Turnarounds without Charters

The 2010 reform that set UP’s takeover in motion sparked other Boston public school interventions as well. A dozen of the lowest-performing “Level 4” BPS schools underwent a SIG-funded restructuring under either the federal transformation or turnaround model (BPS refers to all twelve as “turnaround schools”). These schools, three of which serve middle school grades, were given a longer day and assigned enhanced performance monitoring. Five school leaders were replaced, while teachers at seven schools had to re-apply for their positions and many were not re-hired. How do the gains from these non-charter interventions compare with the effects of a charter takeover? We use our grandfathering research design to evaluate and contrast non-charter, SIG-funded turnarounds at the three middle schools (Orchard Gardens, Henry Dearborn, and Harbor) with grandfathering results at UP.²⁶

Our grandfathering IV strategy for Dearborn and Harbor – which serve grades 6-8 – uses the UP matching scheme by comparing 6th and 7th grade students enrolled in one of the two legacy schools in the fall of 2009 to students not eligible for grandfathering but who share a baseline (5th grade) school.

²⁶Orchard Gardens and Harbor are pilot schools, a BPS model examined in Abdulkadiroğlu et al. (2011).

For Orchard Gardens, a K-8 school, we replicate the RSD design by matching grandfathering-eligible 6th and 7th grade students to control students attending similar schools in the previous baseline grade, where similarity is defined by the deciles of combined average math and ELA test scores (in place of RSD’s SPS bins). Control students in both designs are also matched on baseline special education status, and subsidized lunch eligibility, race, and sex. Table 1 sketches the relevant cohort timing.

As in the notional Gavin experiment, students eligible for grandfathering into the reformed Harbor and Dearborn schools are mostly African American, while those in the Orchard Gardens grandfathering cohort are mostly Hispanic. Also as in the Gavin analysis, we see a gap in baseline scores in the comparison by grandfathering status for both sets of turnarounds. This is again eliminated with additional lagged (that is, pre-baseline) score controls. Pre-baseline to baseline year score growth looks similar for grandfathered and matched controls, with or without additional lagged (in this case, pre-pre-baseline) score controls. These and other comparisons involving turnaround schools are reported in Appendix Table A8. Follow-up rates are similar in the grandfathering-eligible and comparison groups (as can be seen in Table A4), and balance is preserved within the sample for which test score outcomes are measured (Table A8).

In contrast with the impact estimates for students grandfathered into UP, grandfathering into Dearborn and Harbor appears to have had little effect on math scores and increased ELA scores only moderately. By contrast, gains for students grandfathered into Orchard Gardens are similar to those enjoyed by the grandfathered cohort at UP. These results emerge clearly from the comparisons of score trajectories for grandfathering-eligible students and their ineligible matches in Figures 5 and 6, as well as from the grandfathering IV estimates reported in Table 9. In particular, turnaround enrollment generates an estimated average yearly gain of only 0.02σ in math and of 0.17σ in ELA for Dearborn and Harbor, while estimated Orchard Gardens restructuring effects run around $0.31\text{-}0.35\sigma$.

Why do the Orchard Garden effects look like those at UP, while two other turnarounds generated much more modest results? All three middle school turnarounds, as with UP, benefited from a sizable injection of federal SIG funds, an increased focus on teacher performance, and a longer school day. But the experience of Orchard Gardens, one of Boston’s lowest-performing middle schools pre-reform, is notable for the intensity of its restructuring (ER Strategies, 2013). At \$3.73 million over three years, Orchard Garden received roughly three times the SIG funding received by Dearborn, Harbor, and UP. Orchard Gardens also replaced over 80% of its pre-turnaround teaching staff (INSTLL, 2013), and instituted a far longer school day than the other two middle school turnarounds (by the second turnaround year, Dearborn and Harbor had extended instruction time by only 30 minutes a day, while 6th-8th graders at Orchard Gardens saw as much as 3.5 hours added to their schedule on some days

(Time and Learning, 2013)).²⁷ This echoes changes at UP, which replaced all legacy school teachers and added two hours to the school day.

In addition to more instruction time, the Orchard Gardens turnaround enjoyed much more autonomy in its restructuring, which it used to institute many charter-like practices. These include the hiring of a Chief Operating Officer and a Director of Professional Development and Data (a practice seen in Massachusetts charters but rare in traditional public schools), extensive use of data and performance monitoring software, a restructuring of the district-prescribed math, special education, and English-language learner curricula, an intensified emphasis on student comportment and a climate of high expectations, and the recruitment of young, relatively inexperienced teachers with the help of outside organizations such as Teach for America and Teach Plus (Time and Learning, 2013; ER Strategies, 2013).²⁸ Table A2 shows an average teacher age at Orchard Gardens of around 30, a full decade younger than the average teacher at the Dearborn and Harbor turnarounds and close to the UP average of 28. Roughly half of the Orchard Gardens post-turnaround staff were new to the district, compared with only 11 percent at Dearborn and Harbor (all of UP’s initial teacher roster came from outside BPS). These statistics reinforce the view that, in addition to being unprecedented in scope and relatively resource-intensive, the Orchard Gardens turnaround had much in common with the approach taken by effective charter management organizations in RSD and Boston.

6 Summary and Conclusions

Charter school takeovers in the New Orleans Recovery School District appear to have generated substantial achievement gains for a highly disadvantaged student population that enrolled in charters passively. Our analysis uncovers even larger effects for students grandfathered into Boston’s first in-district charter middle school, UP Academy. These results contribute to a growing body of evidence showing large positive effects of No Excuses urban charter schools on a range of student outcomes.

Our econometric framework addresses important methodological issues that arise in the grandfathering research design. First, while legacy school enrollment provides a valuable source of exogenous variation in charter exposure, the grandfathering IV strategy should adjust for violations of the exclusion restriction due to legacy exposure itself. Second, in an environment with schools of many types,

²⁷In addition to instruction time, the extended school day also featured homework and tutoring sessions, as well as career-oriented apprenticeships led by Citizen Schools, one of Orchard Garden’s several outside partners in the first few years of turnaround.

²⁸Many of the charter-like features of the Orchard Gardens turnaround, particularly its pedagogical similarities with a No Excuses model, were revealed in a March 2015 interview conducted with former principal Andrew Bott. In an interview with us around the same time, Massachusetts Teach For America (TFA) coordinator Josh Biber noted that roughly a quarter of Orchard Garden’s post-turnaround staff were newly-placed TFA corps members.

charter treatment effects may be diluted by charter attendance in the control group. A simple 2SLS procedure allowing for multiple treatment channels generates an easier-to-interpret counterfactual. In practice, cleaning up the non-charter counterfactual substantially boosts estimates of RSD takeover effects on math, from about 0.21σ to 0.36σ , while leaving the smaller ELA estimates largely unchanged. The grandfathering research design can be applied to other incumbency-based interventions, not necessarily involving charter schools, so these solutions should be useful elsewhere as well.

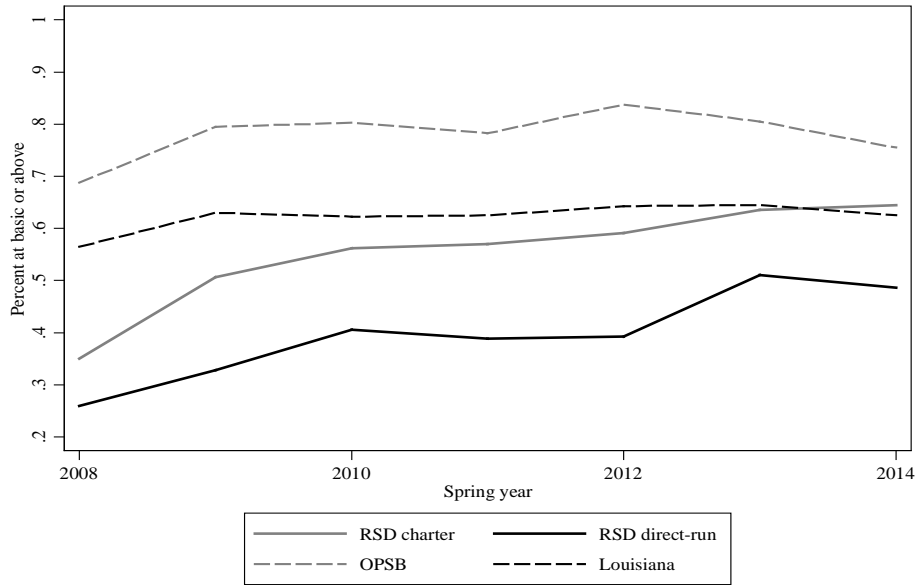
The strong results for RSD and the comparison of estimates from grandfathering and lottery-based research designs for Boston’s UP Academy weigh against the view that urban charter lottery applicants enjoy an unusually large and unrepresentative benefit from charter attendance because they’re highly motivated or uniquely primed to benefit from the education these schools offer. Boston and RSD takeovers generate gains for their passively enrolled students that are broadly similar to, and sometimes even larger than, the lottery estimates reported in Angrist et al. (2013) for a sample of Massachusetts urban charters.

The achievement gains generated by takeover enrollment also exceed those seen for two of Boston’s three turnaround middle schools. Nevertheless, Boston’s Orchard Gardens turnaround appears to have generated gains about as large as those estimated for the UP grandfathering cohort. The fact that Orchard Gardens is clearly the most charter-like of Boston’s non-charter turnarounds seems likely to account for much of this differential impact, and the relative success of the Orchard Gardens turnaround and of the in-district charter model appears to have not gone unnoticed in Boston. In 2014, BPS upgraded Orchard Gardens from a Level 4 to a Level 1 school (the highest ranking), while Harbor and Dearborn retained the low-performing status of Level 3 and Level 4, respectively. Citing a lack of turnaround improvement, BPS officials approved plans in December 2014 to again reconstitute Dearborn, this time with the help of BPE (formerly the Boston Plan for Excellence) which also operates an elementary Horace Mann in-district charter school (BPS, 2014). In their proposal, BPE pressed the district for “Horace Mann-like autonomies,” presented as an essential component to a successful Dearborn conversion (Balonon-Rosen, 2014).

Our findings echo those of Walters (2014) in highlighting the importance of charter access. In a pioneering effort to streamline charter admissions and broaden school choice, RSD introduced in 2012 a district-wide school assignment scheme known as OneApp. OneApp combines all RSD schools, direct-run and charter, using the tools of market design to increase access and improve school-to-student matching (Abdulkadiroğlu et al., 2014b). Denver, the District of Columbia, and Newark use similarly unified enrollment systems (Ash, 2013). Other districts however have resisted attempts to centralize school assignment in general and to integrate charter and direct-run assignment in particular

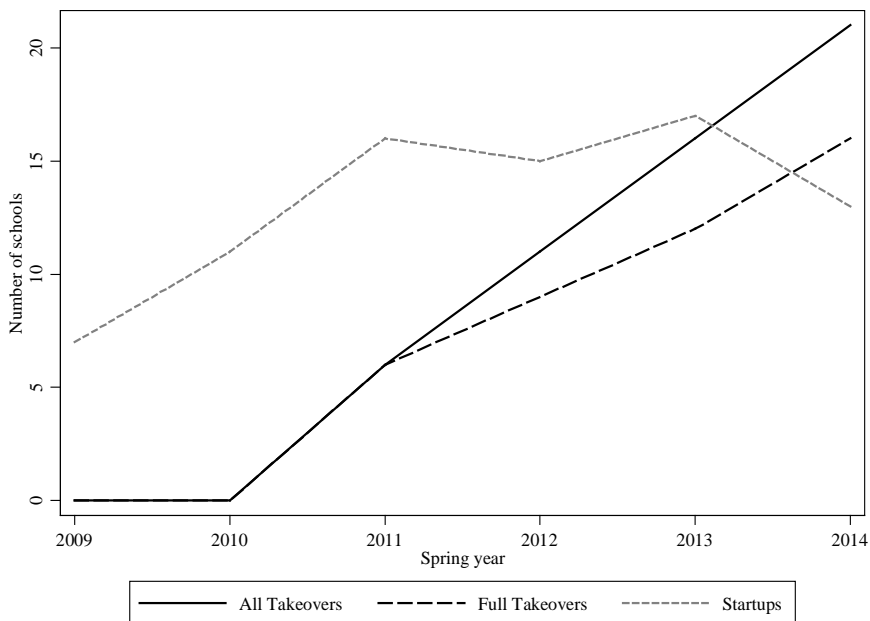
(including OPSB; see, for example Drellinger (2013)). The results reported here suggest the possibility of substantial gains from centralized school assignment mechanisms that, like OneApp, promote charter attendance among students who might not otherwise choose to apply.

Figure 1: Math scores in RSD and elsewhere



Notes: These figures plot the average percentage of RSD, OPSB, and Louisiana students that achieve basic or above status on LEAP/iLEAP math (Figure 1a) or ELA (Figure 1b) exams in 5th-8th grades. Scores for OPSB and Louisiana are from <https://www.louisianabelieves.com/resources/library/test-results>. Statistics plotted are unweighted averages across grades for each year, and are computed separately for students enrolled in RSD charter and RSD direct-run schools.

Figure 2: Charter school expansion in RSD



Notes: This figure plots the number of New Orleans Recover School District charter schools (serving any grades) created between academic years 2008-09 and 2013-14 (excluding alternative schools). Takeovers are charter schools tied to closure of a legacy school, with seats reserved in the new school for legacy school students. Full takeovers are takeover schools (excluding charter mergers and principal-led conversions) that grandfather all grades at the legacy school in a single academic year. Startup schools are those not directly tied to a legacy school, with all seats filled in the first year through open enrollment.

Figure 3a: Test scores in the RSD grandfathering sample

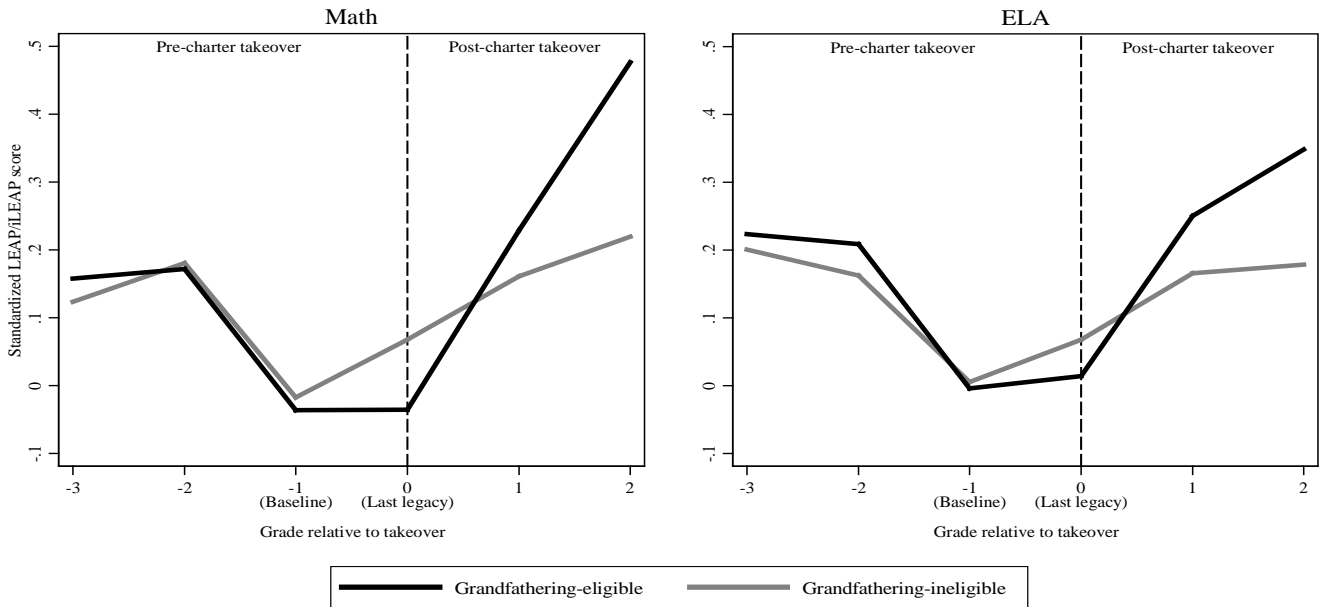
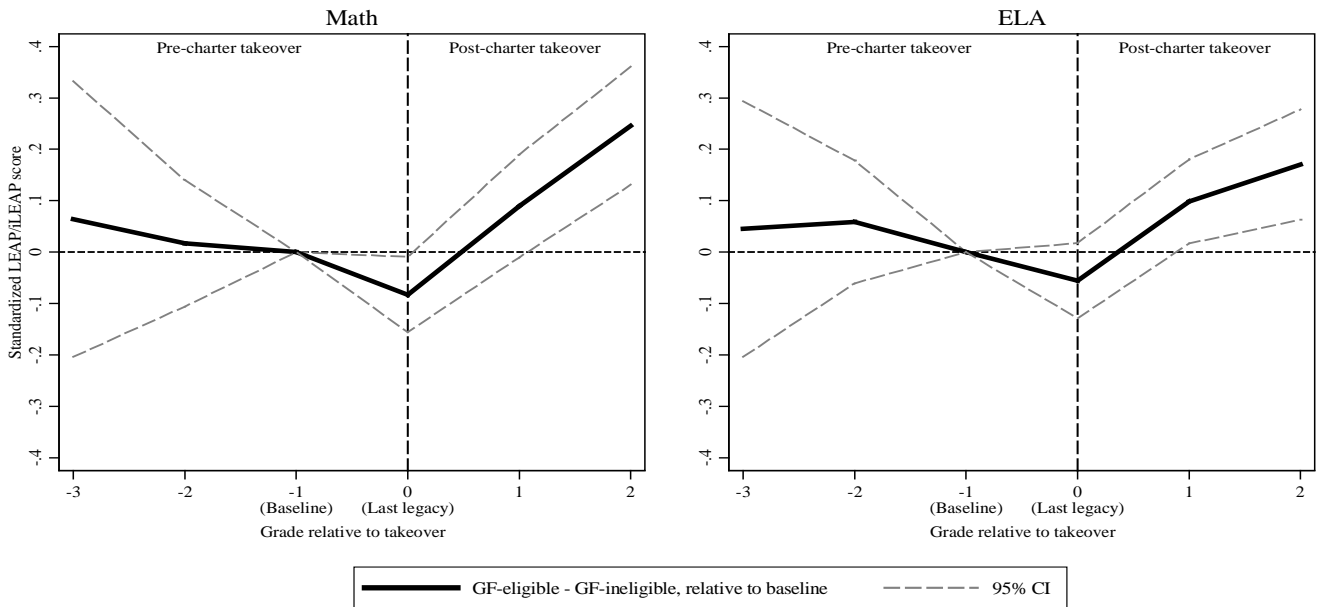


Figure 3b: RSD grandfathering DD



Notes: Figure 3a plots average LEAP/iLEAP math and ELA scores of students in the RSD legacy middle school matched sample. Figure 3b plots achievement growth relative to the baseline grade. Estimates in both figures control for matching cell fixed effects. Scores are standardized to have mean zero and standard deviation one within each year and grade in the set of direct-run schools in New Orleans RSD.

Figure 4a: Test scores in the UP grandfathering sample

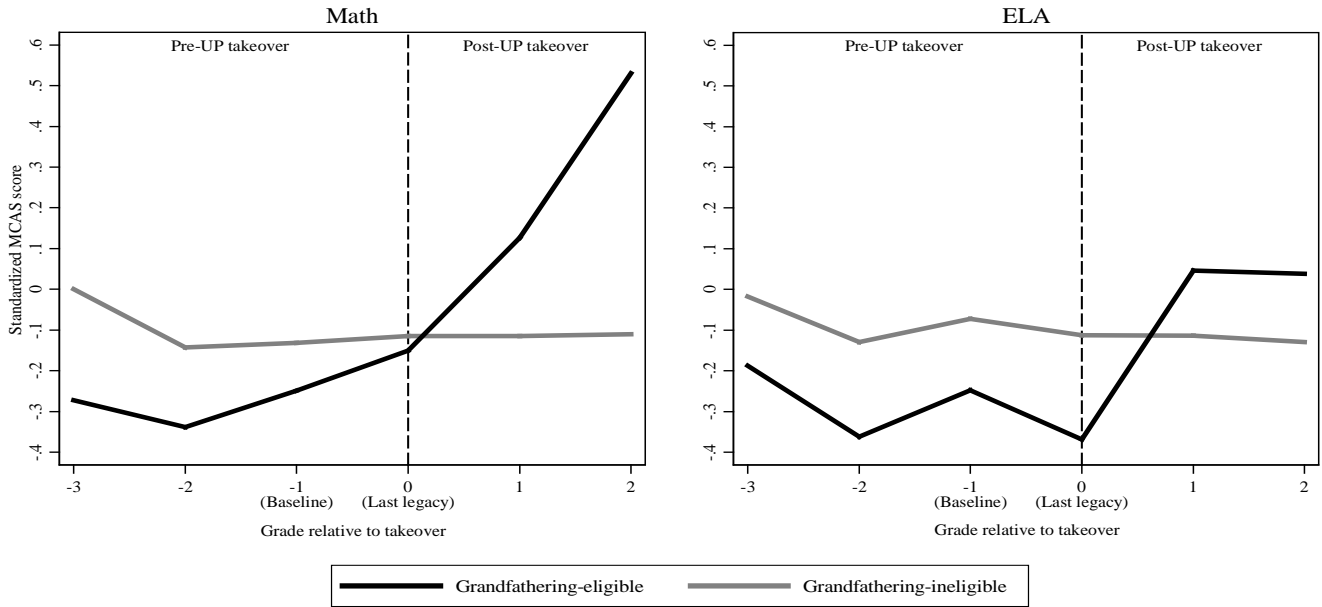
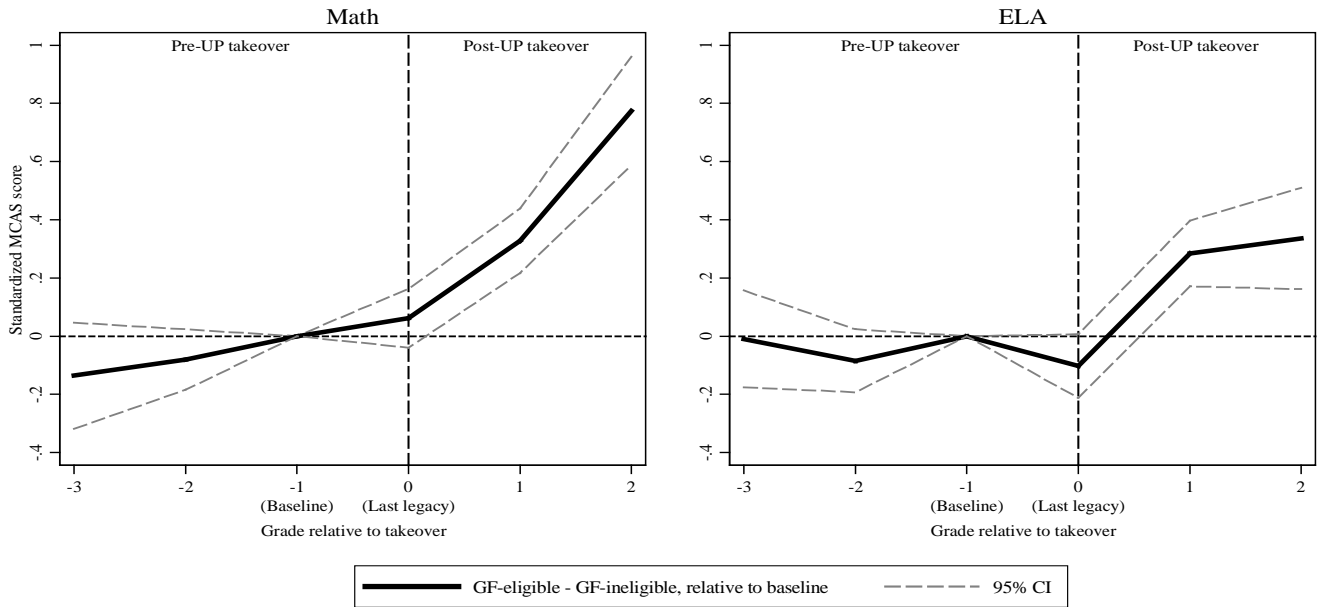


Figure 4b: UP grandfathering DD



Notes: Figure 4a plots average MCAS math and ELA scores of students in the Gavin Middle School matched sample. Figure 4b plots achievement growth relative to the baseline grade. Estimates in both figures control for matching cell fixed effects. Scores are standardized to have mean zero and standard deviation one within each year and grade in BPS.

Figure 5a: Test scores in the Dearborn/Harbor grandfathering sample

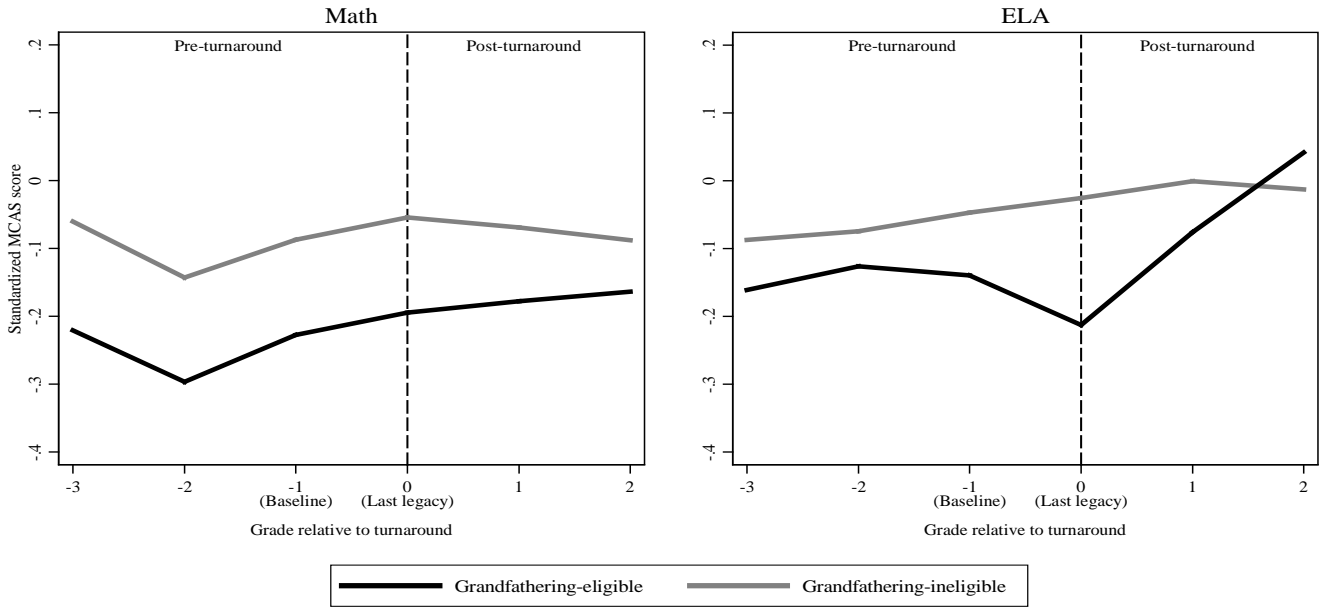
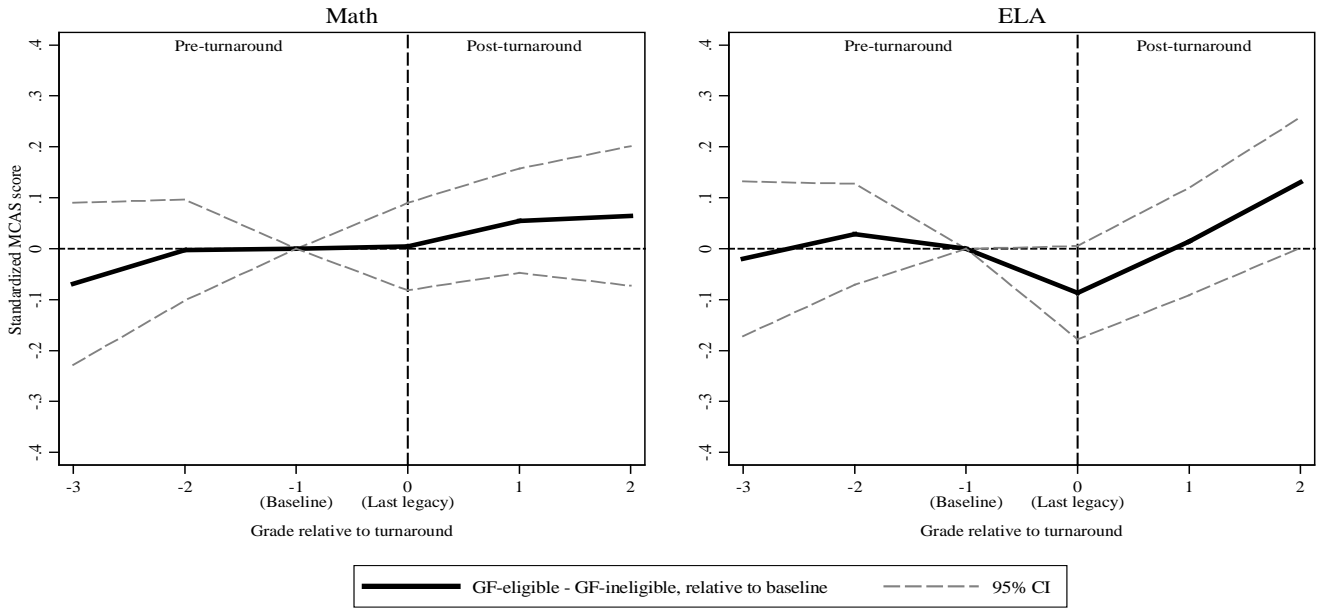


Figure 5b: Dearborn/Harbor grandfathering DD



Notes: Figure 5a plots average MCAS math and ELA scores of students in the Dearborn and Harbor legacy middle school matched sample. Figure 5b plots achievement growth relative to the baseline grade. Estimates in both figures control for matching cell fixed effects. Scores are standardized to have mean zero and standard deviation one within each year and grade in BPS.

Figure 6a: Test scores in the Orchard Gardens grandfathering sample

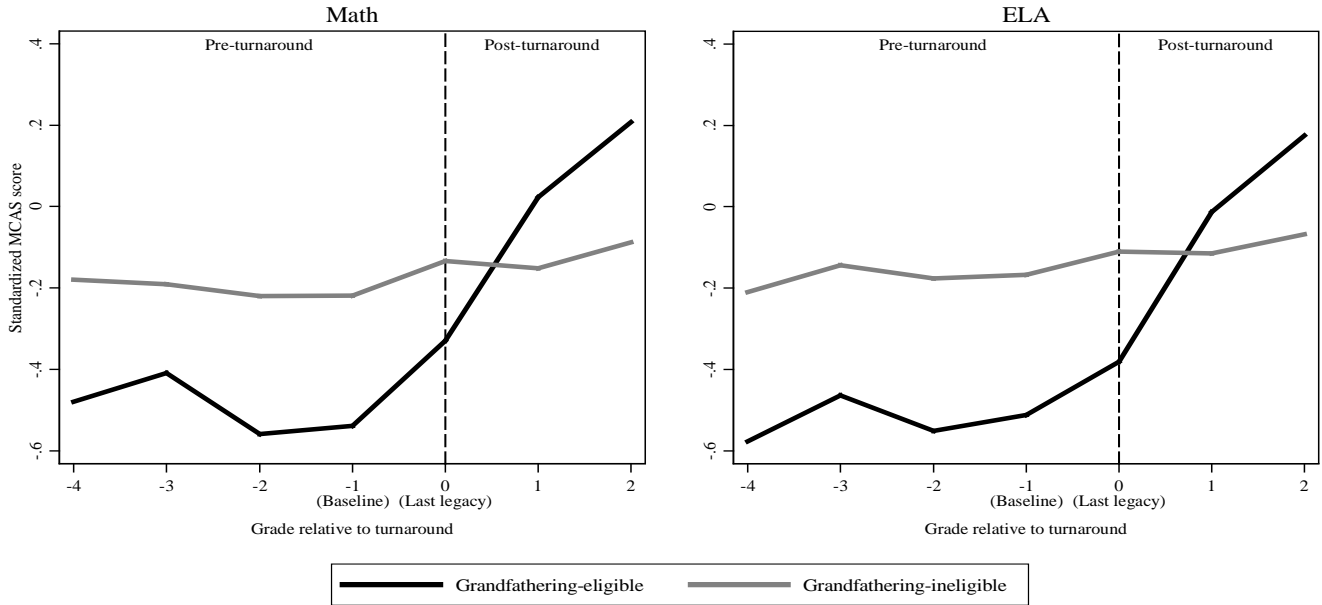
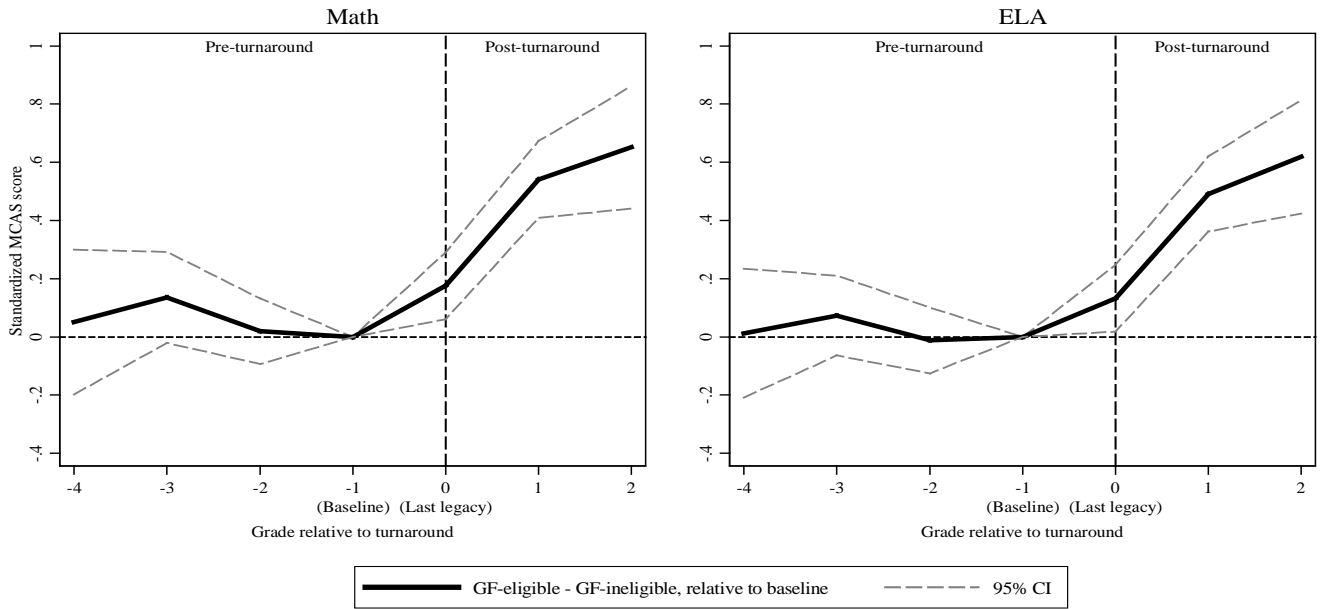


Figure 6b: Orchard Gardens grandfathering DD



Notes: Figure 6a plots average MCAS math and ELA scores of students in the Orchard Gardens legacy middle school matched sample. Figure 6b plots achievement growth relative to the baseline grade. Estimates in both figures control for matching cell fixed effects. Scores are standardized to have mean zero and standard deviation one within each year and grade in BPS.

Table 1: Timing in the grandfathering research design

| | RSD | | | | Boston | | | | | |
|-----------------------------------|----------|--|----------|----------|-------------|----------|-----------------|----------|-----------------|----------|
| | | | | | UP | | Dearborn/Harbor | | Orchard Gardens | |
| Baseline (matching) grade | 3 | 4 | 5 | 6 | 5 | 5 | 5 | 5 | 5 | 6 |
| Legacy enrollment grade | 4 | 5 | 6 | 7 | 6 | 7 | 6 | 7 | 6 | 7 |
| First takeover grade | 5 | 6 | 7 | 8 | 7 | 8 | 7 | 8 | 7 | 8 |
| Second takeover grade | 6 | 7 | 8 | | 8 | | 8 | | 8 | |
| Third takeover grade | 7 | 8 | | | | | | | | |
| Fourth takeover grade | 8 | | | | | | | | | |
| Legacy enrollment years (schools) | | 2009-10 (5) 2010-11 (1) 2011-12 (1) 2012-13 (4) | | | 2010-11 (1) | | 2009-10 (2) | | 2009-10 (1) | |

Notes: This table summarizes grade-based timing for matching, grandfathering eligibility, and takeover outcomes in the RSD and Boston analysis samples. Grandfathering eligibility is determined by enrollment in the fall of the legacy enrollment year, while matching uses information from the baseline grade. Outcomes are from the spring of the corresponding school year of each takeover grade. The number of legacy schools in each academic year is in parentheses.

Table 2: RSD descriptive statistics and grandfathering balance

| | Sample means | | | | Balance coefficients | |
|----------------------------|--------------|----------------------------|---------------------------|----------------------------------|----------------------|----------------------------|
| | RSD | | Analysis sample | | Analysis sample | First exposure year sample |
| | RSD students | Charter-bound RSD students | Takeover charter students | Grandfathering-eligible students | | |
| (1) | (2) | (3) | (4) | (5) | (6) | |
| Hispanic | 0.026 | 0.024 | 0.018 | 0.029 | -- | -- |
| Black | 0.964 | 0.971 | 0.994 | 0.982 | -- | -- |
| White | 0.019 | 0.016 | 0.008 | 0.016 | -- | -- |
| Asian | 0.008 | 0.008 | 0.001 | 0.009 | -- | -- |
| Female | 0.475 | 0.473 | 0.489 | 0.501 | -- | -- |
| Special education | 0.069 | 0.066 | 0.071 | 0.093 | -- | -- |
| Free/reduced price lunch | 0.912 | 0.926 | 0.955 | 0.919 | -- | -- |
| Limited English proficient | 0.017 | 0.016 | 0.013 | 0.020 | 0.000 (0.001) | -0.001 (0.001) |
| N | 14,575 | 11,381 | 1,040 | 763 | 3,503 | 2,572 |
| Baseline math score | -0.001 | 0.019 | -0.320 | -0.266 | -0.019 (0.048) | -0.042 (0.052) |
| N | 12,960 | 10,565 | 1,038 | 760 | 3,500 | 2,570 |
| Baseline math gain | -0.099 | -0.084 | -0.261 | -0.254 | 0.007 (0.069) | 0.009 (0.081) |
| N | 4,871 | 4,099 | 330 | 241 | 1,235 | 993 |
| Baseline ELA score | 0.000 | 0.022 | -0.303 | -0.261 | -0.009 (0.048) | -0.032 (0.055) |
| N | 12,967 | 10,572 | 1,040 | 762 | 3,502 | 2,572 |
| Baseline ELA gain | -0.105 | -0.097 | -0.181 | -0.182 | -0.015 (0.072) | 0.001 (0.079) |
| N | 4,879 | 4,105 | 330 | 241 | 1,235 | 993 |

Notes: This table reports sample means and coefficients from regressions of the variable in each row on a grandfathering eligibility dummy indicating enrollment in an RSD takeover legacy school in the fall of the academic year prior to takeover. Baseline test score gains are relative to the previous pre-baseline grade. All regressions include matching cell fixed effects (cells are defined by race, sex, special education status, subsidized lunch eligibility, baseline grade and year, and baseline school SPS scores in five-point bins). The sample in columns 3-6 is restricted to students enrolled in an RSD direct-run school at baseline. Column 1 reports means for a sample of RSD students in the same baseline years as the analysis sample, while column 2 is restricted to those students that enroll in an RSD charter school in grades following the baseline. Column 3 reports means for students that enroll in a takeover charter in potential takeover grades, while column 4 describes students enrolled in a legacy school. Robust standard errors are reported in parentheses.

*significant at 10%; **significant at 5%; ***significant at 1%

Table 3: Grandfathering IV estimates of RSD takeover attendance effects

| | | Comparison | 2SLS estimates | | |
|--|------------|------------|----------------|-------------|-------------------|
| | | group mean | OLS | First stage | Attendance effect |
| | | (1) | (2) | (3) | (4) |
| A. All grades | | | | | |
| 5th-8th grades | Math | -0.089 | 0.123*** | 1.073*** | 0.212*** |
| | (N: 5,625) | | (0.020) | (0.052) | (0.038) |
| | ELA | -0.092 | 0.082*** | 1.075*** | 0.143*** |
| | (N: 5,621) | | (0.018) | (0.052) | (0.039) |
| B. By grade | | | | | |
| 5th & 6th grades | Math | -0.091 | 0.099*** | 0.738*** | 0.165** |
| | (N: 2,579) | | (0.035) | (0.041) | (0.068) |
| | ELA | -0.116 | 0.023 | 0.745*** | 0.101 |
| | (N: 2,579) | | (0.033) | (0.042) | (0.070) |
| 7th & 8th grades | Math | -0.086 | 0.133*** | 1.355*** | 0.231*** |
| | (N: 3,046) | | (0.020) | (0.070) | (0.037) |
| | ELA | -0.071 | 0.104*** | 1.352*** | 0.171*** |
| | (N: 3,042) | | (0.019) | (0.070) | (0.036) |
| C. By potential exposure | | | | | |
| First exposure year (5th-8th grades) | Math | -0.105 | 0.200*** | 0.659*** | 0.230*** |
| | (N: 2,553) | | (0.044) | (0.023) | (0.069) |
| | ELA | -0.103 | 0.099** | 0.659*** | 0.197*** |
| | (N: 2,553) | | (0.043) | (0.023) | (0.068) |
| Second exposure year (6th-8th grades) | Math | -0.151 | 0.168*** | 1.148*** | 0.332*** |
| | (N: 1,664) | | (0.031) | (0.061) | (0.058) |
| | ELA | -0.124 | 0.101*** | 1.158*** | 0.158*** |
| | (N: 1,664) | | (0.028) | (0.061) | (0.051) |
| Third & fourth exposure year (7th & 8th grades) | Math | 0.015 | 0.097*** | 1.698*** | 0.117*** |
| | (N: 1,408) | | (0.022) | (0.131) | (0.042) |
| | ELA | -0.033 | 0.077*** | 1.698*** | 0.094** |
| | (N: 1,404) | | (0.020) | (0.132) | (0.043) |

Notes: This table reports OLS and 2SLS estimates of the effects of RSD takeover charter enrollment on 5th-8th grade LEAP/iLEAP math and ELA test scores using the grandfathering eligibility instrument. The sample in columns 2-4 includes RSD direct-run school students matched to a pre-takeover year legacy school student. The endogenous regressor counts the number of years enrolled at a takeover charter prior to testing. All models control for matching strata, limited English proficiency, baseline test scores, and year/grade effects. Robust standard errors, clustered by student, are reported in parentheses. Means in column 1 are outcome grade scores for grandfathering-ineligible matched students.

*significant at 10%; **significant at 5%; ***significant at 1%

Table 4: School choice in the RSD analysis sample

| | All students | | Compliers | |
|---------------------------------|--------------|------------|-------------------------|------------|
| | Z=0 (1) | Z=1 (2) | Z=0 (3) | Z=1 (4) |
| | | | A. First exposure year | |
| Enrolled in study takeover | 0.089 | 0.780 | -- | 1.000 |
| ... in other RSD takeover | 0.072 | 0.032 | 0.087 | -- |
| ... in non-takeover RSD charter | 0.331 | 0.154 | 0.316 | -- |
| ... in RSD direct-run | 0.508 | 0.034 | 0.597 | -- |
| N | 2,027 | 531 | | |
| | | | B. Second exposure year | |
| Enrolled in study takeover | 0.206 | 0.714 | -- | 1.000 |
| ... in other RSD takeover | 0.105 | 0.016 | 0.142 | -- |
| ... in non-takeover RSD charter | 0.395 | 0.223 | 0.393 | -- |
| ... in RSD direct-run | 0.294 | 0.047 | 0.465 | -- |
| N | 1,349 | 318 | | |
| | | | C. Third exposure year | |
| Enrolled in study takeover | 0.277 | 0.754 | -- | 1.000 |
| ... in other RSD takeover | 0.112 | 0.031 | 0.218 | -- |
| ... in non-takeover RSD charter | 0.450 | 0.188 | 0.517 | -- |
| ... in RSD direct-run | 0.161 | 0.026 | 0.265 | -- |
| N | 795 | 191 | | |
| | | | D. Fourth exposure year | |
| Enrolled in study takeover | 0.316 | 0.646 | -- | 1.000 |
| ... in other RSD takeover | 0.167 | 0.051 | 0.030 | -- |
| ... in non-takeover RSD charter | 0.485 | 0.291 | 0.864 | -- |
| ... in RSD direct-run | 0.032 | 0.013 | 0.106 | -- |
| N | 342 | 79 | | |

Notes: This table describes school enrollment in the RSD analysis sample. Columns 1-2 characterize enrollment for grandfathering eligible (Z=1) and ineligible (Z=0) students, while columns 3-4 show the same for grandfathering compliers. Other RSD takeover charters include charter-to-charter conversions, principal-led conversions, and mergers. Non-takeover RSD charters include startup charters created since the 2008-2009 academic year, and charters operating in the RSD as of 2007-2008. Complier means are estimated by the method outlined in Abadie (2003), using a probit specification for $E[Z|X]$ and the same controls as were used to construct the estimates in Table 3.

Table 5: Grandfathering IV estimates of RSD charter attendance effects

| | (1) | (2) | (3) | (4) | (5) |
|-------------------|--------------------------------|---------------------------------|--------------------------------|--------------------------------|--------------------------------|
| A. Math (N:5,625) | | | | | |
| Takeover charter | 0.212*** (0.038) [425.7] | 0.217*** (0.037) [3323.0] | 0.357*** (0.073) [632.7] | | |
| Other RSD charter | | | 0.324** (0.152) [47.1] | | |
| Any RSD charter | | | | 0.385*** (0.071) [223.4] | 0.371*** (0.059) [464.9] |
| Instruments | 1 | 31 | 31 | 1 | 31 |
| B. ELA (N:5,621) | | | | | |
| Takeover charter | 0.143*** (0.039) [424.7] | 0.154*** (0.037) [3319.8] | 0.125 (0.081) [620.6] | | |
| Other RSD charter | | | -0.069 (0.174) [46.3] | | |
| Any RSD charter | | | | 0.257*** (0.072) [228.0] | 0.214*** (0.059) [486.5] |
| Instruments | 1 | 31 | 31 | 1 | 31 |

Notes: This table reports 2SLS estimates of the effects of study takeover and other RSD charter enrollment on 5th-8th grade LEAP/iLEAP math and ELA test scores. The sample includes RSD direct-run school students matched to a pre-takeover year legacy school student as described in Table 2. The endogenous regressors count the number of years enrolled in RSD charters prior to testing. The instrument for columns 1 and 4 is grandfathering eligibility. For columns 2, 3, and 4, grandfathering eligibility was interacted with baseline year, special education status, and SPS bin cells. All models control for matching strata, limited English proficiency, baseline test scores, and year/grade effects. Robust standard errors, clustered by student, are reported in parentheses. Angrist-Pischke multivariate first-stage F statistics are reported in brackets.

*significant at 10%; **significant at 5%; ***significant at 1%

Table 6: UP descriptive statistics and grandfathering balance

| | Sample means | | | | Balance coefficients | | |
|----------------------------|---------------------|-----------------------------------|-----------------|--------------------------------------|-----------------------|---------------------------|---------------------------|
| | Boston | | Analysis sample | | Analysis sample | | First exposure |
| | Boston students (1) | Charter-bound Boston students (2) | UP students (3) | Grandfathering-eligible students (4) | No score controls (5) | Lagged score controls (6) | Lagged score controls (7) |
| Hispanic | 0.346 | 0.275 | 0.240 | 0.241 | -- | -- | -- |
| Black | 0.407 | 0.516 | 0.511 | 0.469 | -- | -- | -- |
| White | 0.135 | 0.152 | 0.124 | 0.152 | -- | -- | -- |
| Asian | 0.072 | 0.024 | 0.089 | 0.100 | -- | -- | -- |
| Female | 0.483 | 0.502 | 0.489 | 0.483 | -- | -- | -- |
| Special education | 0.226 | 0.186 | 0.267 | 0.317 | -- | -- | -- |
| Free/reduced price lunch | 0.804 | 0.752 | 0.951 | 0.928 | -- | -- | -- |
| Limited English proficient | 0.231 | 0.131 | 0.342 | 0.307 | 0.045 (0.032) | 0.034 (0.033) | 0.026 (0.033) |
| N | 8,506 | 1,563 | 225 | 290 | 1,203 | 1,060 | 998 |
| Baseline math score | 0.006 | 0.171 | -0.286 | -0.253 | -0.117* (0.070) | -0.040 (0.053) | -0.032 (0.055) |
| N | 8,054 | 1,530 | 210 | 258 | 1,142 | 1,037 | 983 |
| Baseline math gain | 0.023 | 0.087 | 0.083 | 0.058 | 0.006 (0.055) | -0.016 (0.060) | -0.005 (0.062) |
| N | 7,468 | 1,355 | 195 | 239 | 1,059 | 975 | 925 |
| Baseline ELA score | 0.010 | 0.177 | -0.273 | -0.235 | -0.177*** (0.065) | -0.012 (0.053) | -0.014 (0.054) |
| N | 7,935 | 1,527 | 208 | 254 | 1,105 | 1,036 | 982 |
| Baseline ELA gain | 0.023 | 0.054 | 0.140 | 0.158 | 0.063 (0.059) | 0.004 (0.060) | -0.005 (0.061) |
| N | 7,373 | 1,356 | 193 | 235 | 1,038 | 973 | 923 |

Notes: This table reports sample means and coefficients from regressions of the variable in each row on a grandfathering eligibility dummy indicating enrollment in Gavin Middle School in 6th or 7th grade in the fall of 2010. Baseline test score gains are relative to the previous pre-baseline grade. All regressions include matching cell fixed effects (cells are defined by race, sex, special education status, subsidized lunch eligibility, and 5th grade school and year). Regressions in columns 6 and 7 also control for lagged MCAS scores (pre-baseline for baseline demographics and test scores, pre-pre-baseline for baseline score gains). The sample in columns 3-6 is restricted to students enrolled at a BPS school at baseline. Column 1 reports means for a sample of Boston students in the same baseline years as the analysis sample, while column 2 is restricted to students from the Boston sample who enroll in a Boston charter school in grades 6-8. Column 3 reports means for students in the analysis sample who enroll at UP in grades 7 and 8, while column 4 describes students enrolled at Gavin Middle School in the fall of 2010. Robust standard errors are reported in parentheses.
 *significant at 10%; **significant at 5%; ***significant at 1%

Table 7: Grandfathering IV estimates of UP attendance effects

| | | Comparison group | | 2SLS estimates | |
|---|------------|--------------------------|----------|----------------|-------------------|
| | | mean | OLS | First stage | Attendance effect |
| | | (1) | (2) | (3) | (4) |
| | | A. All grades | | | |
| 7th-8th grades | Math | -0.233 | 0.400*** | 1.051*** | 0.321*** |
| | (N: 1,543) | | (0.032) | (0.040) | (0.039) |
| | ELA | -0.214 | 0.296*** | 1.040*** | 0.394*** |
| | (N: 1,539) | | (0.035) | (0.041) | (0.044) |
| | | B. By potential exposure | | | |
| First exposure year (7th & 8th grades) | Math | -0.214 | 0.365*** | 0.822*** | 0.325*** |
| | (N: 1,028) | | (0.047) | (0.025) | (0.048) |
| | ELA | -0.195 | 0.475*** | 0.809*** | 0.495*** |
| | (N: 1,025) | | (0.055) | (0.026) | (0.060) |
| Second exposure year (8th grade) | Math | -0.272 | 0.408*** | 1.541*** | 0.324*** |
| | (N: 515) | | (0.038) | (0.087) | (0.044) |
| | ELA | -0.252 | 0.221*** | 1.543*** | 0.271*** |
| | (N: 514) | | (0.042) | (0.087) | (0.049) |

Notes: This table reports OLS and 2SLS estimates of the effects of UP enrollment on 7th and 8th grade MCAS math and ELA test scores using the grandfathering eligibility instrument. The sample in columns 2-4 includes BPS students matched to a 2010-11 6th or 7th grade Gavin Middle School student. The endogenous regressor counts the number of years enrolled at UP prior to testing. All models control for matching strata, limited English proficiency, baseline test scores, and year/grade effects. Robust standard errors, clustered by student, are reported in parentheses. Means in column 1 are outcome grade scores for grandfathering-ineligible matched students.

*significant at 10%; **significant at 5%; ***significant at 1%

Table 8: Lottery IV estimates of UP attendance effects

| | | Comparison group mean (1) | OLS (2) | 2SLS estimates | | |
|--|--------------------|---------------------------------|---------------------|------------------------|-----------------------|--------------------------|
| | | | | First stage | | Attendance effect (5) |
| | | | | Immediate offer (3) | Waitlist offer (4) | |
| A. All grades | | | | | | |
| 6th-8th grades | Math (N: 2,202) | 0.059 | 0.301*** (0.022) | 0.760*** (0.063) | 0.562*** (0.067) | 0.270*** (0.056) |
| | ELA (N: 2,205) | 0.103 | 0.148*** (0.020) | 0.759*** (0.063) | 0.562*** (0.067) | 0.118** (0.051) |
| B. By potential exposure | | | | | | |
| First exposure year (6th & 7th grades) | Math (N: 881) | 0.056 | 0.347*** (0.044) | 0.519*** (0.034) | 0.397*** (0.038) | 0.365*** (0.086) |
| | ELA (N: 882) | 0.058 | 0.239*** (0.044) | 0.521*** (0.034) | 0.394*** (0.038) | 0.220** (0.088) |
| Second & third exposure year (7th & 8th grades) | Math (N: 1,321) | 0.061 | 0.294*** (0.021) | 0.921*** (0.088) | 0.665*** (0.091) | 0.242*** (0.054) |
| | ELA (N: 1,323) | 0.129 | 0.131*** (0.020) | 0.918*** (0.088) | 0.668*** (0.091) | 0.083* (0.047) |

Notes: This table reports OLS and 2SLS estimates of the effects of UP enrollment on 6th-8th grade MCAS test scores using 6th and 7th grade lottery offer instruments. The sample in columns 2-4 includes Boston students entering 6th grade in the 2011-12 and 2012-13 academic years and 7th grade in the 2011-12 academic year with baseline demographic information. The endogenous regressor counts the number of years enrolled at UP prior to testing. The instruments are immediate and waitlist offer dummies. Immediate offer is equal to one when a student is offered a seat immediately following the lottery in March, while waitlist offer is equal to one for students offered seats later, up through the end of September. All models control for cohort dummies and student race, sex, special education status, limited English proficiency, subsidized lunch status, baseline test scores, and year/grade effects. Robust standard errors, clustered by student, are reported in parentheses. Means in column 1 are outcome grade scores for applicants not given an immediate or waitlist offer.

*significant at 10%; **significant at 5%; ***significant at 1%

Table 9: Grandfathering IV estimates of BPS turnaround attendance effects

| | Comparison group mean (1) | OLS (2) | 2SLS estimates | |
|---------------------------------|---------------------------------|---------------------|---------------------|--------------------------|
| | | | First stage (3) | Attendance effect (4) |
| A. Dearborn/Harbor (UP design) | | | | |
| Math (N: 1,915) | -0.149 | 0.019 (0.028) | 0.971*** (0.043) | 0.022 (0.035) |
| ELA (N: 1,921) | -0.063 | 0.089*** (0.033) | 0.981*** (0.043) | 0.174*** (0.040) |
| B. Orchard Gardens (RSD design) | | | | |
| Math (N: 2,246) | -0.234 | 0.307*** (0.042) | 1.113*** (0.046) | 0.367*** (0.048) |
| ELA (N: 2,256) | -0.179 | 0.352*** (0.044) | 1.114*** (0.046) | 0.397*** (0.052) |

Notes: This table reports OLS and 2SLS estimates of the effects of BPS turnaround enrollment on 7th and 8th grade MCAS math and ELA test scores using the grandfathering eligibility instrument. The sample in columns 2-6 includes BPS students matched to a 2009-10 6th or 7th student at Dearborn, Harbor, or Orchard Gardens. The endogenous regressor counts the number of years enrolled at the turnaround prior to testing. First exposure year treated and untreated complier outcomes in columns 5 and 6 are estimated as in Table 9. All models control for matching strata, limited English proficiency, baseline test scores, and year/grade effects. Robust standard errors, clustered by student, are reported in parentheses. Means in column 1 are outcome grade scores for grandfathering-ineligible matched students.

*significant at 10%; **significant at 5%; ***significant at 1%

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A Econometric Appendix

Theorem 1. Under Assumptions 1-4,

$$\frac{E[Y^g - Y^l|Z = 1] - E[Y^g - Y^l|Z = 0]}{E[D|Z = 1] - E[D|Z = 0]} = E[Y_{11}^g - Y_{10}^g|D_1 > D_0] = E[Y_{01}^g - Y_{00}^g|D_1 > D_0].$$

Proof: Using monotonicity (Assumption 2) to partition the $Z = 1$ and $Z = 0$ populations into second-period subpopulations of always-takers, never-takers, and compliers, we have:

$$\begin{aligned} E[Y^g - Y^l|Z = 1] - E[Y^g - Y^l|Z = 0] &= E[Y^g - Y^l|D_0 = 1, Z = 1]P(D_0 = 1|Z = 1) \\ &\quad + E[Y^g - Y^l|D_1 = 0, Z = 1]P(D_1 = 0|Z = 1) \\ &\quad + E[Y^g - Y^l|D_1 > D_0, Z = 1]P(D_1 > D_0|Z = 1) \\ &\quad - E[Y^g - Y^l|D_0 = 1, Z = 0]P(D_0 = 1|Z = 0) \\ &\quad - E[Y^g - Y^l|D_1 = 0, Z = 0]P(D_1 = 0|Z = 0) \\ &\quad - E[Y^g - Y^l|D_1 > D_0, Z = 0]P(D_1 > D_0|Z = 0), \\ (8) \quad &= \left(E[Y_{11}^g - Y_1^l|D_0 = 1] - E[Y_{01}^g - Y_0^l|D_0 = 1] \right) P(D_0 = 1) \\ &\quad + \left(E[Y_{10}^g - Y_1^l|D_1 = 0] - E[Y_{00}^g - Y_0^l|D_1 = 0] \right) P(D_1 = 0) \\ &\quad + \left(E[Y_{11}^g - Y_1^l|D_1 > D_0] - E[Y_{00}^g - Y_0^l|D_1 > D_0] \right) P(D_1 > D_0), \end{aligned}$$

where the second equality follows from independence (Assumption 1).

As a consequence of Assumption 4, we have

$$(9) \quad E[Y_{11}^g - Y_1^l|D_0 = 1] = E[Y_{01}^g - Y_0^l|D_0 = 1]$$

$$(10) \quad E[Y_{11}^g - Y_1^l|D_1 > D_0] = E[Y_{01}^g - Y_0^l|D_1 > D_0]$$

and

$$(11) \quad E[Y_{00}^g - Y_0^l|D_1 = 0] = E[Y_{10}^g - Y_1^l|D_1 = 0]$$

$$(12) \quad E[Y_{00}^g - Y_0^l|D_1 > D_0] = E[Y_{10}^g - Y_1^l|D_1 > D_0]$$

Equations (9) and (11) imply that the first two terms in equation (8) are zero. Equation (12) and the fact that, by independence and monotonicity, $E[D|Z = 1] - E[D|Z = 0] = P(D_1 > D_0)$ imply further that

$$\begin{aligned} \frac{E[Y^g - Y^l|Z = 1] - E[Y^g - Y^l|Z = 0]}{E[D|Z = 1] - E[D|Z = 0]} &= E[Y_{11}^g - Y_1^l|D_1 > D_0] - E[Y_{10}^g - Y_1^l|D_1 > D_0] \\ &= E[Y_{11}^g - Y_{10}^g|D_1 > D_0]. \end{aligned}$$

From (10), it follows similarly that

$$\begin{aligned} \frac{E[Y^g - Y^l | Z = 1] - E[Y^g - Y^l | Z = 0]}{E[D | Z = 1] - E[D | Z = 0]} &= E[Y_{01}^g - Y_0^l | D_1 > D_0] - E[Y_{00}^g - Y_0^l | D_1 > D_0] \\ &= E[Y_{01}^g - Y_{00}^g | D_1 > D_0] \end{aligned}$$

□

We assume throughout that Assumptions 1-4 hold conditional on a set of mutually-exclusive and exhaustive matching cell dummies, d_j . These covariates add a layer of cross-cell averaging to the within-cell average-causal-effects interpretation of the 2SLS estimand. With matching-cell fixed effects as the only controls, the covariate parameterization is saturated. Therefore, as shown by Abadie (2003), a 2SLS regression of $Y^g - Y^l$ on D and $\{d_j\}$ that instruments D by Z identifies the treatment coefficient in a regression of $Y^g - Y^l$ on $\{d_j\}$ and D for compliers (this follows from the linearity of the propensity score in a saturated model). Moreover, Angrist (1998) shows that, in general, a regression of this sort (saturated controls with a single additive treatment effect) generates a weighted-average of cell-specific treatment-control comparisons, with weights proportional to the within-cell variance of treatment. Thus, the IV estimand for this specification can be written as a variance-weighted average of cell-specific LATEs.

In practice, the grandfathering estimates reported here come from models that include additive controls for baseline covariates and year-of-test controls, as well as a full set of matching-cell fixed effects. Since the additional controls are independent of Z within cells, the weighted average interpretation of a IV estimand with fully interacted controls is unchanged, while we can expect estimates of models that include additional controls to be more precise.

Extension of Theorem 1 to an Ordered Treatment

Suppose treatment, D , takes on values in the set $\{0, 1, \dots, \bar{d}\}$. Assumption 1 is modified to accommodate this ordered treatment, below:

Assumption 1' (*Independence*) $\{Y_0^l, Y_1^l, Y_{00}^g, \dots, Y_{0\bar{d}}^g, Y_{10}^g, \dots, Y_{1\bar{d}}^g, D_0, D_1\} \perp\!\!\!\perp Z$.

We similarly modify Assumption 4:

Assumption 4' (*Strong Gains Exclusion*) $P(Y_{1d}^g - Y_1^l = Y_{0d}^g - Y_0^l) = 1$ for $d \in \{0, 1, \dots, \bar{d}\}$.

Under Assumptions 1', 2, 3, and 4' we can use Theorem 1 in Angrist and Imbens (1995) to show

$$\begin{aligned} \frac{E[Y^g - Y^l|Z = 1] - E[Y^g - Y^l|Z = 0]}{E[D|Z = 1] - E[D|Z = 0]} &= \sum_{d=1}^{\bar{d}} \frac{E[(Y_{1d}^g - Y_1^l) - (Y_{1d-1}^g - Y_1^l)|D_1 \geq d > D_0]P(D_1 \geq d > D_0)}{\sum_{d=1}^{\bar{d}} P(D_1 \geq d > D_0)} \\ &= \sum_{d=1}^{\bar{d}} \frac{E[Y_{1d}^g - Y_{1d-1}^g|D_1 \geq d > D_0]P(D_1 \geq d > D_0)}{\sum_{d=1}^{\bar{d}} P(D_1 \geq d > D_0)}. \end{aligned}$$

Likewise,

$$\begin{aligned} \frac{E[Y^g - Y^l|Z = 1] - E[Y^g - Y^l|Z = 0]}{E[D|Z = 1] - E[D|Z = 0]} &= \sum_{d=1}^{\bar{d}} \frac{E[(Y_{0d}^g - Y_0^l) - (Y_{0d-1}^g - Y_0^l)|D_1 \geq d > D_0]P(D_1 \geq d > D_0)}{\sum_{d=1}^{\bar{d}} P(D_1 \geq d > D_0)} \\ &= \sum_{d=1}^{\bar{d}} \frac{E[Y_{0d}^g - Y_{0d-1}^g|D_1 \geq d > D_0]P(D_1 \geq d > D_0)}{\sum_{d=1}^{\bar{d}} P(D_1 \geq d > D_0)}. \end{aligned}$$

As for our interpretation of the Bernoulli treatment estimand, the assumptions behind this interpretation of the ordered estimand are assumed to hold within matching cells, and our IV estimates of ordered treatment effects come from models that include a full set of matching-cell fixed effects. These models also include a set of additive controls that should be unrelated to the instruments conditional on matching controls. Angrist and Imbens (1995) show that the IV estimand in models with an ordered treatment, saturated covariate controls, and a saturated first stage (that is the first stage interacts Z with $\{d_j\}$) can be written as an average causal effect of a one-unit increase in treatment intensity for ordered-treatment compliers. In practice, we omit interactions Z with $\{d_j\}$ from the first stage, except where these are required to identify models with multiple endogenous regressors. As can be seen by comparing the estimates in columns 1 and 2 of Table 5, the omission of higher-order terms from the instrument list is of little empirical consequence for models with a single treatment effect.

Weakening Assumption 4

We modify the potential outcomes model described by equations (1) and (2) to allow legacy enrollment to change legacy-year and later potential outcomes to differing degrees. To keep the presentation compact, we assume away variation in conditional mean functions across compliant subpopulations. Specifically, we assume here that

$$(13) \quad E[Y_z^l|X, Z] = E[Y_z^l|X] = \alpha_1(X) + z\gamma(X)$$

$$(14) \quad E[Y_{zd}^g|X, Z] = E[Y_{zd}^g|X] = \alpha_2(X) + \lambda z\gamma(X) + d\beta,$$

where λ is a parameter assumed to lie in the unit interval. Covariates are required to identify the model when λ is unknown, so (13) and (14) are specified with additive covariate effects included (for the purposes of this discussion, matching cell dummies are subsumed in the covariate vector, X).

As in Chamberlain’s (1984) panel models with unobserved individual effects scaled by an unknown time-varying factor loading, models with $\lambda \neq 1$ are identified by quasi-differencing, then moving the lagged score term (legacy-grade scores, in this case) to the right hand side and treating this term as endogenous. The extra instruments needed to identify this model come from interacting Z with X . This leads us to omit covariate interactions from the specification of the treatment effect.²⁹

Theorem 2. Suppose Assumptions 1-3 hold for a Bernoulli covariate, x , and that the conditional mean functions for potential outcomes satisfy (13) and (14) when X is replaced with x . Suppose also that the first stage varies with x , so that $P(D_1 > D_0|x = 0) \neq P(D_1 > D_0|x = 1)$. Then the IV estimand for a regression of Y^g on the pair (Y^l, D) , treated as endogenous and instrumented with (Z, Zx) , while controlling for exogenous x , identifies the parameters λ and β in equation (14).

Proof. Note that $Y^l = Y_Z^l$ and $Y^g = Y_{ZD}^g$. Equations (13) and (14) therefore imply

$$\begin{aligned} E[Y^l|Z, x] &= \alpha_1(x) + \gamma(x)Z \\ E[Y^g|Z, x] &= \alpha_2(x) + \lambda\gamma(x)Z + \beta E[D|Z, x] \end{aligned}$$

for $j = 0, 1$. From here, we get the reduced form

$$(15) \quad E[Y^g|Z, x] = [\alpha_2(x) - \lambda\alpha_1(x)] + \lambda E[Y^l|Z, x] + \beta E[D|Z, x].$$

This completes the proof since (15) is the reduced form for the 2SLS procedure described in the theorem. □

In practice, our 2SLS models for RSD use 30 interactions of the grandfathering instrument with baseline year, SPED status, and SPS bins instead of the single interaction used to establish the theorem (for UP, we have over 60 interactions with baseline year, SPED status, and baseline school). Assuming away treatment effect variation with X , the over-identified model should produce a more efficient estimate of the parameters than the just-identified estimand.

Appendix Table A9 reports key parameter estimates from the setup described in Theorem 2. Consistent with differences-in-differences Figures 3 and 4, legacy year effects in RSD are estimated at about $-.09$ for math and $-.03$ for ELA. The contrast between 2SLS estimates for RSD allowing λ to be a free parameter identified by Theorem 2 and estimates under gains exclusion ($\lambda = 1$) appears in columns 2 and 3 of the table. Although λ is estimated to be about a half, the differences in treatment effects here are modest and not significantly different from zero. As suggested by differences-in-

²⁹See Hull (2014) for a more general approach to identifying treatment effects under parameterized violations of the exclusion restriction.

differences Figures 5 and 6, the legacy year treatment effect for those grandfathered into UP is positive for math and negative for ELA. These estimates are reported in columns 5 and 6 of Table A9. In this case, λ is estimated to be about .63 for math and about .4 for ELA. Allowing λ to be free changes the math takeover effect little, but generates a marginally significant decline in the estimated ELA effect, from .4 to about .31. This decline leaves the comparison of lottery and grandfathering estimates qualitatively unchanged.

B Data Appendix

B.1 New Orleans RSD

The New Orleans RSD grandfathering analysis file is constructed from student enrollment, demographic, and outcome data provided by RSD for school years 2007-2008 through 2013-2014. Enrollment and demographic data include information on all students enrolled in the New Orleans RSD. 4th and 8th grade test score outcomes are from the Louisiana Educational Assessment Program (LEAP); all other outcome grades measure achievement by the integrated LEAP (iLEAP) exam.

Student enrollment and demographics

RSD enrollment data include a June (end-of-year) file for school years 2007-2008 through 2012-2013, and an October file for school years 2011-2012 through 2013-2014. For school year 2013-2014, an additional February file is available. Each enrollment file is a snapshot of the enrollment records at each New Orleans RSD school, and contains information on the first and last dates of attendance of each student in each school and grade over the academic year up to the given month. Enrollment files also include a unique student identifier, the “student ID.” We use information on student names and dates of birth to confirm consistency of student IDs across enrollment files. After resolving any inconsistencies, student IDs are used to match students to LEAP/iLEAP test score files.

Enrollment files contain information on student sex, race, special education status, limited English proficiency status, subsidized lunch eligibility, and school attended.³⁰ We construct a panel dataset capturing demographic and enrollment information for every student in each grade, keeping information from the first calendar year spent in each grade and recording the number of times a grade is subsequently repeated. A student is counted as attending a takeover charter if she enrolls in one for any amount of time. If a student attends multiple non-takeover charter schools within the same year and grade, she is counted as enrolled in the longest-attended school. Attendance duration ties are broken by giving preference to the most recent enrollment. All other attendance ties are broken randomly. Students classified as special education, limited English proficient, or eligible for a free- or reduced-price lunch in any record within a grade retain that designation for that grade.

³⁰Race is coded as black, white, asian, hispanic, and other. In RSD these are not mutually-exclusive categories. Race and gender are grade-invariant characteristics, while SPED, LEP, and free/reduced price lunch status are grade-specific.

LEAP/iLEAP

The LEAP/iLEAP outcomes of interest are math, English Language Arts (ELA), sciences, and social sciences test scores for grades 5 through 8. Tests at the end of the legacy grade and at the end of the baseline matching grade are also used to calculate test score gains and as controls, respectively. The grade configuration of legacy and baseline tests is summarized in Table 1.

Each observation in the LEAP/iLEAP data files corresponds to a student's test results in a particular subject, grade, and year. For each grade, we use scores from the first attempt at a given subject test. The raw test score variables are standardized to have mean zero and standard deviation one within a subject-grade-year in the New Orleans RSD. The standardization excludes scores from students enrolled in alternative schools.

School Performance Scores

School Performance Scores ("SPS") for school years 2007-2008 through 2011-2012 are used to construct matching cells for New Orleans RSD grandfathered students. These scores are obtained from <http://www.louisianabelieves.com/resources/library/performance-scores>.

During the analysis sample years, SPS scores ranged from 0 to 200, where a score below 75 corresponded to an "F" letter grade, and a score above 120 corresponded to an "A" letter grade. Matched cells are constructed by splitting the 0 to 200 range into 5-point bins.

School and teacher characteristics

Class size, per-pupil expenditures (PPE), teacher experience, and average salary are obtained from the Louisiana Department of Education website (<http://www.louisianabelieves.com>).

RSD average class sizes – reported in Table A2 – are based on academic years 2010-2011 and 2011-2012, and are calculated using the midpoint of reported class size ranges, with the exception of the class category size of "34 +," which is coded as an average class size of 34 students. Class size figures reported in columns 3-4 of Table A2 include any full takeover or legacy school for which data were available, including charter-to-charter and high school full takeovers. In particular, schools included in column 3's class size figure are Sarah Towles Reed Elementary, Fannie C. Williams Elementary, Harriet Tubman Elementary School, Joseph S. Clark Senior High, McDonogh 42 Elementary Charter, Joseph A. Craig, Crocker Arts and Technology, H.C. Schaumburg Elementary, Abramson Science and Technology, Pride College Preparatory Academy, Paul B. Habans Elementary, and Murray Henderson Elementary. Column 4's class size figure includes SciTech Academy at Laurel Elementary, Esperanza

Charter, Edgar P. Harney Spirit of Excellence Academy, Gentilly Terrace Elementary, Batiste Cultural Arts Academy at Live Oak Elementary, and Reed Elementary.

RSD teacher experience and salary, also reported in Table A2, are based on operator-level data for the 2010-2011 academic year. PPE are averages over academic years 2008-2009 through 2010-2011. PPE in column 1 is based on aggregate figures reported for all RSD direct-run schools, and exclude one-time expenditures related to Hurricane Katrina. Schools included in column 3's PPE are Gentilly Terrace, E.P. Harney Spirit of Excellence Academy, Batiste Cultural Arts Academy at Live Oak Elementary, John Dibert Community School, SciTech Academy at Laurel Elementary, and Esperanza Charter. Schools included in column 4's PPE are AD. Crossman Esperanza Charter and Harriet Tubman. An adjusted PPE figure for column 1 is provided for better comparability. The adjusted figure excludes excess spending (relative to charters) in operations and management from the reported RSD direct-run figure, as RSD direct-run expenditures include spending on building insurance premiums for all buildings overseen by RSD, including those operated by charters (see Cowen (2011b)).

Grandfathering eligibility and matching

The grandfathering eligibility instrument is based on fall enrollment. For the New Orleans RSD, the instrument is coded by the enrollment designation procedure described above, using attendance data up to October 31. Students that leave a legacy school prior to October 31 are not considered grandfathering-eligible.

For each legacy school, grandfathering-eligible students are those enrolled in grades 4-7 in the fall immediately prior to takeover. These students are matched to grandfathering-ineligible students that share the sex, race, special education status, subsidized lunch eligibility, and SPS 5-point bin of the grandfathered student in their baseline grade and year. Students who are eligible for grandfathering into a takeover charter in multiple grades or who are matched to such a student are retained in the first grade by which they enter the analysis sample.

Appendix Table A3 describes the construction of the RSD grandfathering sample. We identify a total of 1,657 grandfathering-eligible students across all legacy grades of the 11 schools in our analysis. Excluding students without baseline information and those not enrolled in a direct-run school at baseline reduces this sample to 1,019. Matching these students and retaining the first grade observation produces our analysis sample of 763 grandfathering-eligible and 2,410 grandfathering-ineligible students.

B.2 Boston

Our analysis of the UP Charter School of Boston uses student enrollment, demographic, and outcome data provided by the Massachusetts Department of Elementary and Secondary Education for school years 2007-2008 through 2013-2014. We construct two analysis files, one for the UP grandfathering analysis and one for the UP lottery analysis. Boston enrollment and demographic data come from the Student Information Management System (SIMS), a centralized database that covers all public school students in Massachusetts. Test score outcomes are from the Massachusetts Comprehensive Assessment System (MCAS). For the lottery sample, lists of first-time applicants and lottery winners are provided by UP.

Student enrollment and demographics

SIMS data include an end-of-year file and an October file for each school year. As with RSD, each observation in the SIMS refers to a student in a grade of a school in a year. While length of attendance is recorded, the data do not contain exact dates of enrollment. The SIMS also includes a unique student identifier, known as the SASID, which is used to match students to MCAS test score files.

SIMS variables used in our analysis include student sex, race, special education status, limited English proficiency status, subsidized lunch eligibility, and school attended.³¹ We construct a panel dataset capturing demographic and enrollment information for every Massachusetts public school student enrolled in each grade, keeping information from the first calendar year spent in each grade and recording the number of repeated attempts. A student is counted as attending UP if she enrolls for any amount of time. If a student attends multiple schools within the same year and grade, she is counted as enrolled in the longest-attended school. All other attendance ties are broken randomly. Students classified as special education, limited English proficient, or eligible for a free- or reduced-price lunch in any record within a grade retain that designation.

MCAS

The MCAS outcomes of interest are math and ELA test scores in 7th and 8th grade for the UP grandfathering analysis sample, and in grades 6-8 for the UP lottery sample. For the grandfathering analysis, tests at the end of the legacy grade and at the end of the baseline matching grade are also used to calculate test score gains and as controls, respectively. The grade configuration of legacy and baseline tests is summarized in Table 1. For the lottery analysis, baseline tests (from 5th or 6th grade, depending on the application grade) are used as controls.

³¹Race is coded as black, white, asian, hispanic and other, and is mutually-exclusive.

Each observation in the MCAS data files corresponds to a student's test results in a particular subject, grade, and year. For each grade, we use scores from the first attempt at a given subject test. The raw test score variables are standardized to have mean zero and standard deviation one within a subject-grade-year in Boston. The standardization excludes scores from students enrolled in alternative schools.

School and teacher characteristics

Boston student-teacher ratios are based on student data from SIMS and teacher data from EPIMS (Educational Personnel Information Management System). Teacher age and experience are from EPIMS, while PPE and average salary are from Massachusetts Department of Education websites (<http://www.doe.mass.edu>, <http://profiles.doe.mass.edu>, and <http://www.doe.mass.edu/finance/statistics/>).

Student/teacher ratios and teacher characteristics for BPS and Boston charters as reported in Table A2 are averages for academic years 2010-2011 and 2011-2012. Boston student/teacher ratios are based on academic year 2010-2011 for Gavin, Dearborn, Harbor, and Orchard Gardens, and on academic year 2011-2012 for UP. The student/teacher ratio is calculated based on the October SIMS and on teacher full-time equivalents obtained from EPIMS. Columns 5-6 in Table A2 include all Boston traditional public and charter schools serving grades 6-8. In particular, column 6 includes Academy of the Pacific Rim, Boston Collegiate, Boston Preparatory, Brooke Charter Roslindale, Excel Academy, MATCH, Neighborhood House, Roxbury Preparatory, and Smith Leadership Academy.

Boston PPE figures in columns 5-6 of Table A2 refer to fiscal year 2011-2012 and are enrollment-weighted, while adjusted PPE figures exclude special education expenses. PPE figures for Gavin, Dearborn, Harbor, and Orchard Gardens are calculated based on school-specific instructional spending, as reported on Schedule 3 of Boston's FY11 End of Year Financial Report, and on Boston's FY11 average spending on school administration, pupil services, operations and management, and insurance and retirement program. Average teacher salaries for Gavin, Dearborn, Harbor, and Orchard Gardens are calculated from school-specific expenditures on teacher salaries for the academic year 2010-2011, as reported in Schedule 3 of Boston's FY11 End of Year Financial Report, and on the total number of teachers at each school according to EPIMS.

Grandfathering eligibility and matching

The grandfathering instrument is based on fall semester enrollment. For UP the instrument is coded by the enrollment designation procedure described above using data from the October 2010 SIMS.

Grandfathering-eligible students are those enrolled in 6th and 7th grade at Gavin Middle School, and are matched to grandfathering-ineligible students that share the sex, race, special education status, subsidized lunch eligibility, and 5th grade school and year.

We identify a total of 334 students eligible for grandfathering into UP (Appendix Table A3). Excluding students without baseline information and those not enrolled in BPS at baseline reduces this sample to 290. These grandfathering-eligible students and their 913 ineligible matches constitute our Boston grandfathering analysis sample.

Lottery sample

We obtained a list of students applying to UP in Spring 2011 through Spring 2013 for entry in grades 6-8 from school officials. The raw lottery records include each applicant's name, date of birth, contact information, lottery priority group, and lottery number. Three of these admission cohorts were found to have been oversubscribed by first-time applicants: 6th and 7th grade entry in Spring 2011, and 6th grade entry in Spring 2012. Appendix Table A5 describes these cohorts: from a total of 1,418 student names we find 1,015 first-time, non-sibling BPS students whose admission to UP was determined solely by lottery number.

We use student lottery numbers to construct two indicator variables for whether applicants were eligible to receive an offer to attend UP. The *immediate offer* instrument indicates admission offers made on the day of the lottery in March. The *waitlist offer* instrument indicates that a student has a lottery number better than the student with the worst lottery number who was offered admission to UP from the waitlist by the end of September. Overall immediate and waitlist offer rates were 30 and 21 percent, respectively.

UP's lottery rosters do not include SASIDs; these records are matched manually to the SIMS by name, date of birth, application year and application grade. In some cases, this procedure did not produce a unique match and information on town of residence was used to break ties. Our matching procedure successfully located 96% (972) of UP Boston applicants in the SIMS/MCAS database. Excluding student not enrolled in BPS at baseline produces the UP lottery sample of 962 students.

Table A1: RSD full charter takeovers from 2008-09 to 2012-13

| Closure year (spring) | Legacy school | Charter legacy? | Legacy grades | Takeover school | Takeover charter network | "No Excuses" network? | Takeover grades | Study takeover? |
|-----------------------|--|-----------------|---------------|--|--------------------------|-----------------------|-----------------|-----------------|
| 2010 | A.D. Crossman: Esperanza Charter | Yes | K-8 | Esperanza Charter School | Choice | | K-8 | |
| | John Dibert Elementary | | PK-8 | John Dibert Community School | FirstLine | Yes | PK-8 | Yes |
| | Laurel Elementary | | PK-8 | SciTech Academy at Laurel Elementary | ReNEW | Yes | PK-8 | Yes |
| | Live Oak Elementary | | PK-8 | Batiste Cultural Arts Academy at Live Oak Elementary | ReNEW | Yes | PK-8 | Yes |
| 2011 | Harney Elementary | | PK-8 | Edgar P. Harney Spirit of Excellence Academy | Spirit of Excellence | | K-8 | Yes |
| | Gentilly Terrace Elementary | | PK-8 | Gentilly Terrace School | New Beginnings | | PK-8 | Yes |
| | Harriet Tubman Elementary | Yes | PK-8 | Harriet Tubman Charter School | Crescent City | Yes | K-8 | |
| | Joseph S. Clark Senior High | | 9-12 | Joseph S. Clark Preparatory High School | FirstLine | Yes | 9-12 | |
| 2012 | Sarah Towles Reed Elementary | | PK-8 | Dolores T. Aaron Elementary | ReNEW | Yes | PK-8 | Yes |
| | McDonogh #42 Charter | Yes | PK-8 | McDonogh 42 Elementary Charter School | Choice | | PK-8 | |
| | Joseph A. Craig School | | PK-8 | Joseph A. Craig Charter School | Friends of King | Yes | PK-8 | Yes |
| | John McDonogh Senior High | | 9-12 | John McDonogh High School | Future is Now | | 9-12 | |
| 2013 | Pride College Preparatory Academy | Yes | K-5 | Mildred Osborne Charter School | Arise Academy | | PK-6 | |
| | Crocker Arts and Technology School | Yes | PK-5 | Lawrence D. Crocker College Prep | New Orleans College Prep | | PK-5 | |
| | Paul B. Habans Elementary School | | PK-6 | Paul Habans Charter School | Crescent City | Yes | PK-6 | Yes |
| | Murray Henderson Elementary School | | 1-5 | Paul Habans Charter School | Crescent City | Yes | PK-6 | Yes |
| | H.C. Schaumburg Elementary School | | PK-8 | Schaumburg Elementary | ReNEW | Yes | PK-8 | Yes |
| | Abramson Science and Technology School | | K-8 | Schaumburg Elementary | ReNEW | Yes | PK-8 | Yes |

Notes: This table lists RSD's full charter takeovers from the 2008-09 to the 2012-13 academic years. Study takeovers are those involving a public-to-charter middle school takeover. "No Excuses" networks are identified using charter applications and school or network web sites. There were no full charter takeovers in the 2008-09 academic year.

Table A2: RSD and Boston school and teacher characteristics

| | Boston | | | | | | | | | |
|---|--------------------|-----------------|------------|--------------|----------------------------|--------------------|-----------|----------|---------------------|----------------------|
| | RSD direct-run (1) | RSD charter (2) | Legacy (3) | Takeover (4) | BPS (5) | Boston charter (6) | Gavin (7) | UP (8) | Dearborn/Harbor (9) | Orchard Gardens (10) |
| Student-teacher ratio | -- | -- | -- | -- | 12.3 | 11.8 | 13.5 | 11.7 | 10.1 | 8.8 |
| Average class size | 20.3 | 19.4 | 19.9 | 19.7 | -- | -- | -- | -- | -- | -- |
| Per-pupil expenditures | | | | | A. School characteristics | | | | | |
| Reported | \$13,104 | \$11,056 | \$11,682 | \$10,934 | \$17,948 | \$14,938 | \$15,054 | \$14,586 | \$19,497 | \$16,333 |
| Adjusted | \$11,104 | -- | -- | -- | \$15,419 | \$14,000 | \$12,119 | \$13,441 | \$16,646 | \$15,289 |
| | | | | | B. Teacher characteristics | | | | | |
| Avg age | -- | -- | -- | -- | 42 | 32 | 41 | 28 | 41 | 30 |
| Proportion young (age ≤ 28) | -- | -- | -- | -- | 0.10 | 0.40 | 0.03 | 0.60 | 0.13 | 0.34 |
| Average years of experience in district | 12.4 | 7.0 | -- | -- | 12 | 3 | 13 | 1 | 9 | 3 |
| Proportion new (experience ≤ 1) | 0.18 | 0.28 | -- | -- | 0.06 | 0.28 | 0.03 | 1.00 | 0.11 | 0.49 |
| Proportion veteran (experience > 5) | 0.62 | 0.36 | -- | -- | 0.69 | 0.15 | 0.62 | 0.00 | 0.59 | 0.26 |
| Average salary | \$48,080 | \$46,416 | -- | -- | \$81,963 | \$66,696 | \$77,251 | \$60,459 | \$68,861 | \$61,978 |

Notes: Figures in columns 1-4 are calculated using data from <http://www.louisianabelieves.com>. Figures in columns 5-10 are based on student data from SIMS (Student Information Management System), teacher data from EPIMS (Educational Personnel Information Management System), as well as on expenditures and teacher salary data from <http://www.doe.mass.edu>, <http://profiles.doe.mass.edu>, and <http://www.doe.mass.edu/finance/statistics/>. See Data Appendix for calculation details.

Table A3: RSD and Boston grandfathering cohorts

| Closure Spring Year | Legacy school | Takeover charter network | Grandfathering-eligible students | | | | Comparison students |
|------------------------|-------------------|-----------------------------|----------------------------------|-----------------------------|-------------------------------|---------------------------|------------------------|
| | | | All | With baseline covariates | Direct-run/BPS at baseline | Unique analysis sample | |
| A. RSD | | | | | | | |
| 2010 | John Dibert | FirstLine | 140 | 92 | 86 | 78 | 204 |
| | Laurel | ReNEW | 176 | 102 | 96 | 76 | 873 |
| | Live Oak | ReNEW | 152 | 76 | 72 | 65 | 673 |
| | Harney | Spirit of Excellence | 121 | 63 | 56 | 55 | 425 |
| | Gentilly Terrace | New Beginnings | 156 | 111 | 107 | 106 | 543 |
| 2011 | Sarah Towles Reed | ReNEW | 215 | 143 | 137 | 81 | 267 |
| 2012 | Joseph A. Craig | Friends of King | 216 | 154 | 142 | 86 | 112 |
| 2013 | Paul B. Habans | Crescent City | 232 | 180 | 168 | 87 | 326 |
| | Murray Henderson | Crescent City | 135 | 85 | 66 | 53 | 168 |
| | H.C. Shaumburg | ReNEW | 111 | 81 | 71 | 55 | 274 |
| | Abramson | ReNEW | 25 | 24 | 23 | 21 | 45 |
| | | Pooled RSD: | 1,657 | 1,105 | 1,019 | 763 | 2,410 |
| B. Boston | | | | | | | |
| 2011 | Gavin | UP | 334 | 307 | 290 | 290 | 913 |
| 2010 | Dearborn | | 152 | 126 | 116 | 116 | 379 |
| | Harbor | | 206 | 204 | 200 | 200 | 716 |
| | Orchard Gardens | | 182 | 166 | 166 | 166 | 1,554 |

Notes: This table describes the sample of grandfathering-eligible students and their ineligible matches for the RSD study takeovers, UP, and the Boston non-charter turnarounds. Legacy school students are matched to comparison students by race, sex, baseline grade and year, special education status, subsidized lunch eligibility, and either baseline school SPS scores in five-point bins (RSD), baseline school MCAS score deciles (Orchard Gardens), or baseline school (UP, Harbor, and Dearborn).

Table A4: Grandfathering attrition

| | Sample means | | | | Balance coefficients |
|-----------------------------------|---------------------|------------------------|---------------------------|----------------------------------|----------------------|
| | RSD/Boston | | Analysis sample | | Analysis sample |
| | RSD/Boston students | Charter-bound students | Takeover charter students | Grandfathering-eligible students | |
| | (1) | (2) | (3) | (4) | (5) |
| | | | A. RSD | | |
| Has legacy grade outcomes | 0.749 | 0.856 | 0.958 | 0.936 | 0.003 (0.011) |
| N | 14,575 | 11,381 | 1,040 | 763 | 3,503 |
| Has first exposure year outcomes | 0.671 | 0.774 | 0.828 | 0.710 | 0.008 (0.021) |
| N | 14,575 | 11,381 | 1,040 | 763 | 3,503 |
| Has second exposure year outcomes | 0.633 | 0.733 | 0.814 | 0.738 | 0.031 (0.027) |
| N | 9,390 | 7,534 | 775 | 443 | 2,353 |
| Has third exposure year outcomes | 0.605 | 0.709 | 0.755 | 0.669 | 0.027 (0.034) |
| N | 5,862 | 4,679 | 534 | 290 | 1,505 |
| Has fourth exposure year outcomes | 0.477 | 0.569 | 0.599 | 0.488 | 0.000 (0.050) |
| N | 2,545 | 2,090 | 252 | 162 | 788 |
| | | | B. UP | | |
| Has legacy grade outcomes | 0.910 | 0.974 | 0.938 | 0.893 | -0.012 (0.014) |
| N | 8,506 | 1,563 | 225 | 290 | 1,203 |
| Has first exposure year outcomes | 0.884 | 0.939 | 0.933 | 0.855 | -0.025 (0.018) |
| N | 8,506 | 1,563 | 225 | 290 | 1,203 |
| Has second exposure year outcomes | 0.868 | 0.915 | 0.877 | 0.817 | -0.065* (0.033) |
| N | 7,993 | 1,448 | 130 | 164 | 626 |
| | | | C. BPS turnaround | | |
| Has legacy grade outcomes | 0.908 | 0.971 | 0.973 | 0.969 | 0.010 (0.009) |
| N | 4,995 | 792 | 400 | 482 | 3,075 |
| Has first exposure year outcomes | 0.888 | 0.949 | 0.958 | 0.929 | -0.002 (0.013) |
| N | 4,995 | 792 | 400 | 482 | 3,075 |
| Has second exposure year outcomes | 0.884 | 0.926 | 0.932 | 0.925 | 0.008 (0.018) |
| N | 2,756 | 474 | 220 | 267 | 1,622 |

Notes: This table reports sample means and coefficients from regressions of the variable in each row on a grandfathering eligibility dummy indicating enrollment in a takeover legacy school in the fall of the academic year prior to takeover, controlling for matching strata. Regressions in column 6 also control for pre-baseline MCAS scores. The sample in columns 3-6 is restricted to students enrolled in an RSD direct-run school (panel A) or BPS school (panel B) at baseline. Column 1 reports means for a sample of RSD/Boston students in the same baseline years as the analysis sample, while column 2 is restricted to those students that enroll in an RSD/Boston charter school in grades following the baseline. Column 3 reports means for students that enroll in a takeover school in potential takeover grades, while column 4 describes students enrolled in a legacy school. Robust standard errors are reported in parentheses.

*significant at 10%; **significant at 5%; ***significant at 1%

Table A5: UP lottery records

| | 2011 | | 2012 | Total |
|--|-----------|-----------|-----------|-------|
| | 6th grade | 7th grade | 6th grade | |
| | (1) | (2) | (3) | |
| Total number of records | 791 | 170 | 457 | 1,418 |
| Excluding late applicants | 698 | 81 | 361 | 1,140 |
| Excluding applicants from outside of BPS | 666 | 79 | 323 | 1,068 |
| Excluding siblings of UP students | 652 | 61 | 302 | 1,015 |
| Excluding records not matched to SIMS | 621 | 53 | 298 | 972 |
| In a BPS school at baseline | 619 | 51 | 292 | 962 |

Notes: This table summarizes the sample restrictions imposed for the analysis of UP's lottery applicants.

Table A6: UP lottery descriptive statistics, balance, and attrition

| | Sample means | | | | Balance coefficients (Lottery applicants) | |
|-----------------------------------|-----------------|----------------------------------|--------------------|------------------|--|-------------------|
| | Boston students | Grandfathering-eligible students | Lottery applicants | | Immediate offer | Waitlist offer |
| | (1) | (2) | 6th grade (3) | 7th grade (4) | (5) | (6) |
| A. Balance | | | | | | |
| Hispanic | 0.374 | 0.241 | 0.327 | 0.294 | -0.023 (0.033) | 0.035 (0.037) |
| Black | 0.375 | 0.469 | 0.483 | 0.373 | 0.004 (0.036) | -0.026 (0.040) |
| White | 0.124 | 0.152 | 0.090 | 0.196 | 0.014 (0.022) | -0.005 (0.023) |
| Asian | 0.073 | 0.100 | 0.055 | 0.098 | 0.025 (0.019) | -0.012 (0.019) |
| Female | 0.487 | 0.483 | 0.504 | 0.471 | 0.003 (0.036) | -0.017 (0.040) |
| Special education | 0.222 | 0.317 | 0.231 | 0.275 | 0.032 (0.031) | -0.001 (0.034) |
| Free/reduced price lunch | 0.794 | 0.928 | 0.802 | 0.843 | 0.019 (0.029) | -0.024 (0.032) |
| Limited English proficient | 0.280 | 0.307 | 0.248 | 0.275 | 0.023 (0.032) | -0.035 (0.034) |
| N | 6,744 | 290 | 911 | 51 | 962 | 962 |
| Baseline math test score | 0.003 | -0.253 | -0.054 | -0.081 | 0.003 (0.066) | -0.064 (0.073) |
| N | 6,501 | 258 | 897 | 48 | 945 | 945 |
| Baseline ELA test score | 0.006 | -0.235 | -0.030 | -0.169 | -0.060 (0.066) | 0.018 (0.074) |
| N | 6,387 | 254 | 890 | 47 | 937 | 937 |
| B. Attrition | | | | | | |
| Has first exposure year outcomes | 0.917 | 0.855 | 0.924 | 0.843 | -0.016 (0.020) | 0.033 (0.021) |
| N | 6,744 | 290 | 911 | 51 | 962 | 962 |
| Has second exposure year outcomes | 0.878 | 0.817 | 0.872 | 0.784 | -0.034 (0.025) | 0.014 (0.028) |
| N | 6,744 | 164 | 911 | 51 | 962 | 962 |
| Has third exposure year outcomes | 0.826 | | 0.814 | | -0.047 (0.039) | -0.038 (0.044) |
| N | 4,294 | | 617 | | 617 | 617 |

Notes: This table reports sample means and coefficients from regressions of the variable in each row on either an immediate or waitlist offer dummy. The immediate offer dummy indicates that a lottery applicant was offered a seat in the March lottery, while the waitlist offer dummy indicates that an applicant was eligible for the offer of a seat off the waitlist from March to the end of September. All regressions include lottery risk set dummies. The sample in columns 2-6 is restricted to students enrolled in a BPS school at baseline. Column 1 reports means for a sample of Boston students in the same baseline grades and years as the analysis sample. Robust standard errors are reported in parentheses.

*significant at 10%; **significant at 5%; ***significant at 1%

Table A7: School choice in the UP analysis samples

| | All students | | Compliers | |
|----------------------------|--------------|------------|------------|------------|
| | Z=0 (1) | Z=1 (2) | Z=0 (3) | Z=1 (4) |
| A. Grandfathering | | | | |
| Enrolled in UP | 0.012 | 0.794 | -- | 1.000 |
| ...in other Boston charter | 0.063 | 0.009 | 0.070 | -- |
| ...in BPS | 0.837 | 0.137 | 0.856 | -- |
| ...in other Massachusetts | 0.087 | 0.060 | 0.075 | -- |
| N | 804 | 233 | | |
| B. Lottery | | | | |
| Enrolled in UP | 0.040 | 0.514 | -- | 1.000 |
| ...in other Boston charter | 0.179 | 0.157 | 0.057 | -- |
| ...in BPS | 0.748 | 0.307 | 0.937 | -- |
| ...in other Massachusetts | 0.033 | 0.022 | 0.006 | -- |
| N | 425 | 453 | | |

Notes: This table describes school enrollment in the first exposure year for students in the UP grandfathering and lottery analysis samples. Columns 1-2 in panel A characterize enrollment for grandfathering-eligible (Z=1) and grandfathering-ineligible (Z=0) students, while columns 3-4 show the same for grandfathering compliers. Columns 1-2 in panel B characterize enrollment for "ever offered" (Z=1) and not offered (Z=0) students, while columns 3-4 show the same for lottery offer compliers. Ever offered lottery applicants are those who received either an immediate or a waitlist offer. Complier means in panels A and B are estimated by the method outlined in Abadie (2003), using a probit specification for $E[Z|X]$ and the same controls as were used to construct the estimates in Tables 7 and 8.

Table A8: BPS turnaround descriptive statistics and grandfathering balance

| | Dearborn/Harbor | | | | | | | | | | Orchard Gardens | | | | | | | | | |
|----------------------------|------------------------|--------------------------------------|-----------------------|---------------------------|----------------------------|------------------------|--------------------------------------|-----------------------|---------------------------|----------------------------|--------------------|-------------------------|---------------------------------------|------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| | Sample means | | | | | Balance coefficients | | | | | Sample means | | | | | Balance coefficients | | | | |
| | Analysis sample | | Analysis sample | | First exposure year sample | | Analysis sample | | Analysis sample | | Tumaround students | | Grandfathering-eligible students | | No score controls | | Lagged score controls | | First exposure year sample | |
| | Tumaround students (1) | Grandfathering-eligible students (2) | No score controls (3) | Lagged score controls (4) | Lagged score controls (5) | Tumaround students (6) | Grandfathering-eligible students (7) | No score controls (8) | Lagged score controls (9) | Lagged score controls (10) | | Tumaround students (11) | Grandfathering-eligible students (12) | No score controls (13) | Lagged score controls (14) | Lagged score controls (15) | Lagged score controls (16) | Lagged score controls (17) | Lagged score controls (18) | Lagged score controls (19) |
| Hispanic | 0.189 | 0.212 | -- | -- | -- | 0.618 | 0.608 | -- | -- | -- | | | | | | | | | | |
| Black | 0.700 | 0.674 | -- | -- | -- | 0.326 | 0.337 | -- | -- | -- | | | | | | | | | | |
| White | 0.049 | 0.051 | -- | -- | -- | 0.007 | 0.012 | -- | -- | -- | | | | | | | | | | |
| Asian | 0.008 | 0.013 | -- | -- | -- | 0.007 | 0.006 | -- | -- | -- | | | | | | | | | | |
| Female | 0.514 | 0.503 | -- | -- | -- | 0.500 | 0.530 | -- | -- | -- | | | | | | | | | | |
| Special education | 0.284 | 0.272 | -- | -- | -- | 0.271 | 0.271 | -- | -- | -- | | | | | | | | | | |
| Free/reduced price lunch | 0.872 | 0.858 | -- | -- | -- | 0.826 | 0.825 | -- | -- | -- | | | | | | | | | | |
| Limited English proficient | 0.210 | 0.234 | 0.044 (0.027) | -0.016 (0.026) | -0.012 (0.027) | 0.389 | 0.373 | 0.088** (0.038) | 0.006 (0.037) | -0.003 (0.038) | | | | | | | | | | |
| N | 243 | 316 | 1,355 | 1,239 | 1,177 | 144 | 166 | 1,720 | 1,538 | 1,448 | | | | | | | | | | |
| Baseline math score | -0.374 | -0.326 | -0.165*** (0.060) | -0.007 (0.042) | -0.007 (0.044) | -0.864 | -0.877 | -0.316*** (0.071) | -0.023 (0.054) | -0.025 (0.055) | | | | | | | | | | |
| N | 232 | 307 | 1,325 | 1,223 | 1,165 | 137 | 158 | 1,661 | 1,510 | 1,433 | | | | | | | | | | |
| Baseline math gain | 0.032 | 0.057 | 0.052 (0.047) | 0.052 (0.048) | 0.058 (0.050) | -0.029 | -0.033 | 0.100 (0.062) | 0.097 (0.061) | 0.097 (0.061) | | | | | | | | | | |
| N | 216 | 284 | 1,251 | 1,108 | 1,058 | 124 | 142 | 1,541 | 1,426 | 1,356 | | | | | | | | | | |
| Baseline ELA score | -0.219 | -0.224 | -0.109* (0.064) | 0.012 (0.045) | 0.023 (0.047) | -0.790 | -0.831 | -0.342*** (0.070) | -0.042 (0.051) | -0.054 (0.052) | | | | | | | | | | |
| N | 223 | 295 | 1,312 | 1,226 | 1,167 | 134 | 155 | 1,636 | 1,517 | 1,436 | | | | | | | | | | |
| Baseline ELA gain | 0.042 | 0.047 | -0.001 (0.047) | 0.036 (0.046) | 0.047 (0.048) | 0.017 | 0.011 | 0.058 (0.059) | 0.052 (0.059) | 0.036 (0.059) | | | | | | | | | | |
| N | 203 | 268 | 1,228 | 1,110 | 1,060 | 123 | 141 | 1,519 | 1,433 | 1,360 | | | | | | | | | | |

Notes: This table reports sample means and coefficients from regressions of the variable in each row on a grandfathering eligibility dummy indicating enrollment in Dearborn/Harbor or Orchard Gardens in 6th or 7th grade in the fall of 2009. Baseline test score gains are relative to the previous pre-baseline grade. All regressions include matching cell fixed effects (cells are defined as in the grandfathering analysis of UP for Dearborn/Harbor and as in the analysis of RSD for Orchard Gardens, with average MCAS deciles used in place of SPS bins). Regressions in columns 4, 5, 9, and 10 also control for lagged MCAS scores (pre-baseline for baseline demographics and test scores, pre-pre-baseline for baseline score gains). Regressions in columns 4, 5, 9, and 10 also control for lagged MCAS scores. The sample is restricted to students enrolled at a BPS school at baseline. Columns 1 and 6 report means for students in the analysis sample who enroll at the BPS turnaround in grades 7 and 8, while columns 2 and 7 describes students enrolled at the legacy school in the fall of 2009. Robust standard errors are reported in parentheses. *significant at 10%; **significant at 5%; ***significant at 1%

Table A9: Relaxing gains exclusion

| | RSD | | | UP | | |
|----------------------------|---------------------|----------------------|---------------------|----------------------|----------------------|---------------------|
| | Legacy score (1) | Outcome score (2) | Outcome gain (3) | Legacy score (4) | Outcome score (5) | Outcome gain (6) |
| A. Math | | | | | | |
| Legacy enrollment | -0.088** (0.040) | | | 0.106** (0.046) | | |
| Takeover enrollment | | 0.198*** (0.032) | 0.217*** (0.037) | | 0.370*** (0.035) | 0.337*** (0.036) |
| Legacy score (λ) | | 0.527*** (0.132) | | | 0.629*** (0.104) | |
| Gap to gain estimate | | -0.020 (0.039) | | | 0.034 (0.043) | |
| Instruments | | 31 | 31 | | 61 | 61 |
| N | 2,553 | 5,625 | 5,625 | 1,028 | 1,543 | 1,543 |
| B. ELA | | | | | | |
| Legacy enrollment | -0.030 (0.042) | | | -0.149*** (0.049) | | |
| Takeover enrollment | | 0.139*** (0.030) | 0.154*** (0.037) | | 0.309*** (0.037) | 0.403*** (0.041) |
| Legacy score (λ) | | 0.515*** (0.129) | | | 0.399*** (0.090) | |
| Gap to gain estimate | | -0.015 (0.037) | | | -0.093* (0.051) | |
| Instruments | | 31 | 31 | | 64 | 64 |
| N | 2,553 | 5,621 | 5,621 | 1,025 | 1,539 | 1,539 |

Notes: This table compares 2SLS estimates of takeover enrollment effects on math and ELA test scores under differing assumptions about the persistence of legacy score effects. The outcomes, sample and enrollment endogenous variables are as in Table 4 (RSD) and Table 8 (UP). The instruments in columns 2-3 and 5-6 are grandfathering eligibility interacted with baseline year, special education status, and baseline school SPS bin (RSD) or school (UP). The estimates in columns 2 and 5 treat legacy scores and takeover enrollment as endogenous. Column 1 reports the average effect of grandfathering eligibility on legacy scores, estimated by OLS. All models control for matching strata, limited English proficiency, baseline test scores, and year/grade effects. Robust standard errors, clustered by student, are reported in parentheses.

*significant at 10%; **significant at 5%; ***significant at 1%